MARVETTI, INC.* (A)

Design and Development of a Printing Calculator

In September 1953 the Vice President for Manufacturing of Marvetti, Inc. assigned Harvey Shaw as Project Engineer to design and develop a new printing calculator. Mr. Shaw was a graduate engineer who had been with the firm since 1943. He had previously worked on adding machines and on related types of equipment.

Marvetti, Inc. is a subsidiary of The Overhill Corporation with corporate headquarters and manufacturing operations located in Bound Brook, New Jersey. Marvetti has other plants in the United States as well as in Italy and West Germany. The firm's products can be broadly classed as lying in the data processing field.

Marvetti was founded in 1928 by Fabrizio Marvetti, an Italian technician and inventor. For many years the foundation of the company's product line was a series of rotary desk calculators. Three current, competitive rotary calculators are shown in Exhibit 1. Prices of rotary calculators range from a few hundred dollars for small hand-crank units to over $1000 for full-featured machines. Marvetti also produces adding machines, small electronic computers intended for business applications,

*Fictional name. All names of people and places and all dates used in this case have been disguised.

Prepared in the Design Division of the Department of Mechanical Engineering by John A. Alic under the direction of H.O. Fuchs with financial support from the National Science Foundation.

other types of special purpose office equipment including systems equipment for data transmission and manipulation, and bookkeeping and mail room equipment. The merger with Overhill took place in October 1958. In 1959 Marvetti's gross sales totalled $137 million. In 1960 the company was organized as shown in Exhibit 2. Harvey Shaw was one of 22 engineers in the Calculator Section of the Research and Development Department.

Although adding machines had been marketed for a number of years previously, Marvetti's first adding machine was not introduced until 1947. Three current adding machines are shown in Exhibit 3. While these machines are used mainly for addition and subtraction, competitive advantage is sought through introduction of special features. For instance, Friden 's first adding machine, introduced in 1952, featured a check dial window in which the numbers entered into the keyboard were visible. A digital key depressed on the keyboard of an adding machine results in the rotation of a gear sector by a number of teeth equal to the digit entered. In these Friden machines corresponding numbers from 0 to 9 were inscribed on the circumference of this sector, called the check dial sector, opposite the gear teeth. The mechanism for one check dial sector appears in Exhibit 4. The inscribed number corresponding to the entry appears in the check dial window. The digital entry capacity of a machine is limited by the number of sectors in the machine. Thus, the largest number which can be entered in an adding machine with 10 check dial sectors is 99,999,999.99. This entire number would be visible in the check dial window.

In the 1940's Remington Rand began marketing a printing calculator--a machine resembling an adding machine but with automatic multiplication and division besides the addition and subtraction capabilities. Olivetti and Victor also soon introduced printing calculators. In each of these three machines a record of the arithmetic computations is obtained on a paper tape; all numbers are printed. The printing calculators are also priced lower than rotaries; in 1965 the Victor machine sold for about $475. the Olivetti (called the Olivetti-Underwood since the Italian firm of Olivetti purchased the U.S. company, Underwood) for about $625. Against these advantages are drawbacks in capacity (number of digits which may be manipulated) and speed in comparision with rotary calculators. Other firms were also introducing printing calculators, and as early as 1950 it seemed to some observers at Marvetti that they were cutting into the market for the company's rotary machines.

The basic difference between the operation of a rotary calculator and an adding machine or a printing calculator based on adding machines is that numerical manipulations in a rotary calculator are carried out by continuous unidirectional rotations of gears, while adding machines and related printing calculators manipulate numbers via gears which start, stop, change directions and sometimes reciprocate. For this reason rotary machines are capable of greater operating speeds.

Printing Calculator Development at Marvetti

In the early 1940's a printing calculator project lasting two or three years was under way at Marvetti. Mr. Shaw felt that this project was doomed from the start by efforts to fit the machine components inside a cover which had been designed first.

There were also attempts to add printing to a rotary calculator in the middle 1940's. These were eventually abandoned.

From about the middle of 1950 through 1952 an inventor employed by Marvetti in Italy as a machine serviceman attempted to perfect a printing calculator using a strictly empirical design approach. He built two models; however, this project functioned without aid from the Bound Brook R & D Department, and it progressed no further.

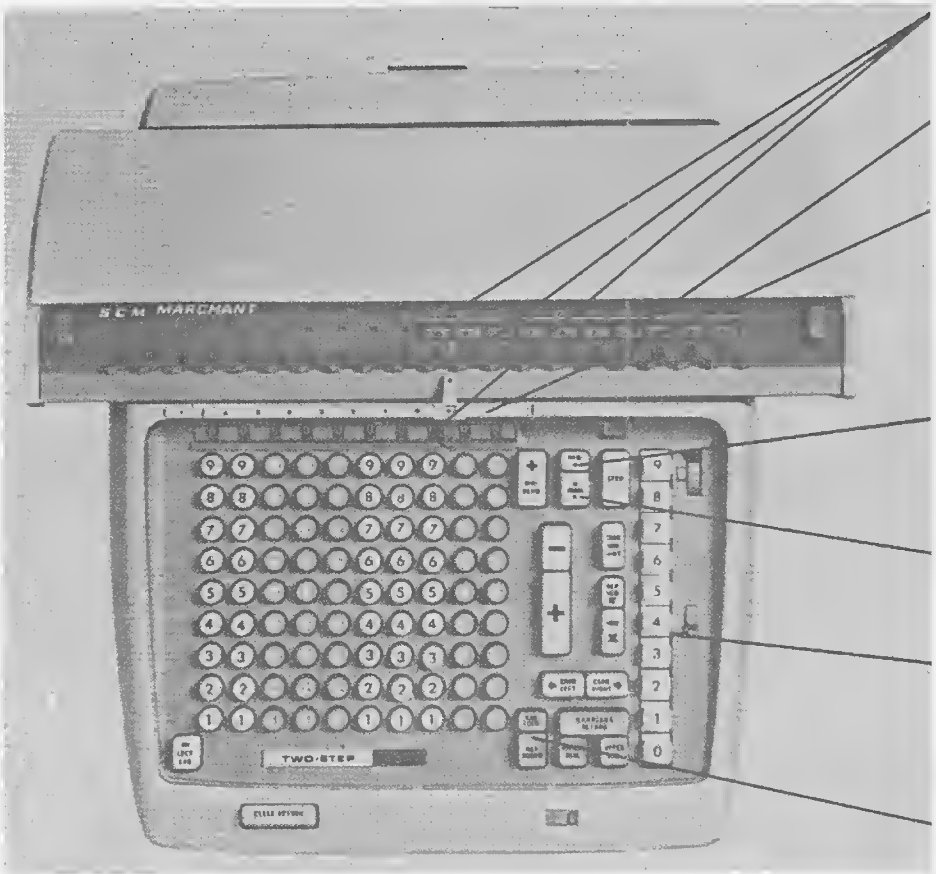
In 1950 a German entrepeneur offered to sell Marvetti the rights to a printing calculator. An assessment and evaluation of the machine followed during the first months of 1951. The machine needed improvement--which was no doubt to be expected. The negotiations were never consummated and the machine was later sold to one of Marvetti's competitors.

During 1951 and 1952 management was not in agreement about the desirability of producing a printing calculator. It was obvious that sales of rotary calculators were dropping; however there was some feeling that introduction of a printing calculator would only cut further into sales of the rotary machines.

When Mr. Shaw was assigned to the printing calculator project in 1953, he felt that it might be a good idea to proceed concurrently with two printing calculators--one would be of relatively conventional design, intended to be competitive with but superior to the Olivetti-Underwood then commonly considered the best available printing calculator. The second would be a much more advanced, high speed machine representing a second generation level of improvement. It was common knowledge in the industry that it had taken Olivetti sixteen years to develop their printing calculator.

MARCHANT MAKES LIFE SIMPLER IN MANY MORE WAYS

While adding the new, we retain the best of the old.



Three-Factor Proof! All multiplication entries and answers show until you begin the next problem.

Push-Button Tabs! You have complete control of carriage movement and positioning.

Automatic "Ready Set" Decimals! Locate the position of the decimal automatically in all operations. Slide-set decimals beside each carriage dial provide quick visual reference for all multiple decimal settings.

One-Step Negative Division! Markup, percentage decrease and complementary division applications are done faster, quieter and better than ever.

Automatic Division! Once again, clearance, carriage return and decimals are completely automatic.

Push-Button Multiplication! Provides instantaneous results in all multiplication operations. The answer is developed while the multiplier is being entered.

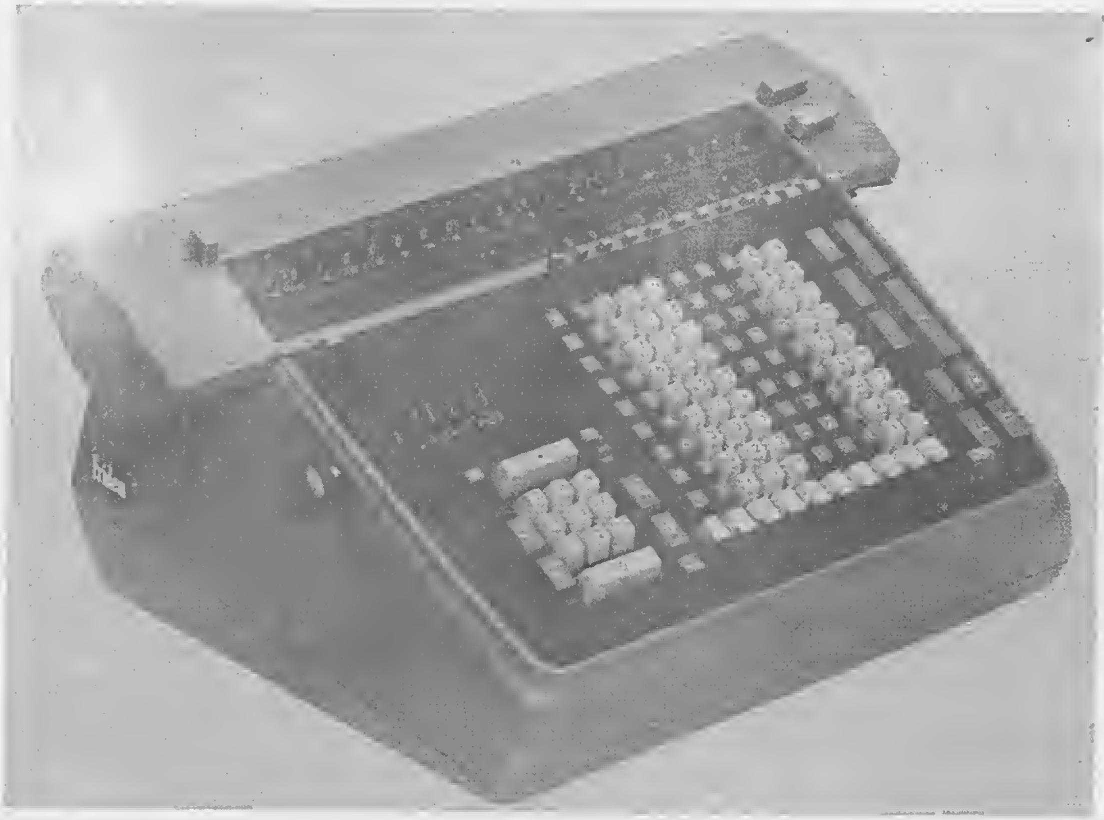
Flexible Keyboard Dial Lock! Constant factors may be held in either a part of or in all of the main keyboard. These factors remain visible throughout repeated operations and bring accuracy to a new high

AND THE TWO-STEP OFFERS THESE ADDITIONAL TIME- AND EFFORT-SAVING CONVENIENCES:

Single-step repeat addition and subtraction with automatic item count. Widely spaced, contoured keys for quicker, surer entry of figures. Constantly meshed proportional gears achieve a cycling speed twice as fast as any other rotary calculator.

SEE HOW THE TWO-STEP WITH INSTA-CLEAR KEYBOARD CAN ADD VERSATILITY, ECONOMY AND EFFICIENCY TO YOUR OPERATION. CALL OR WRITE YOUR SCM MARCHANT REPRESENTATIVE FOR A FREE DEMONSTRATION.

Exhibit 1: Rotary Calculators.



Specifications

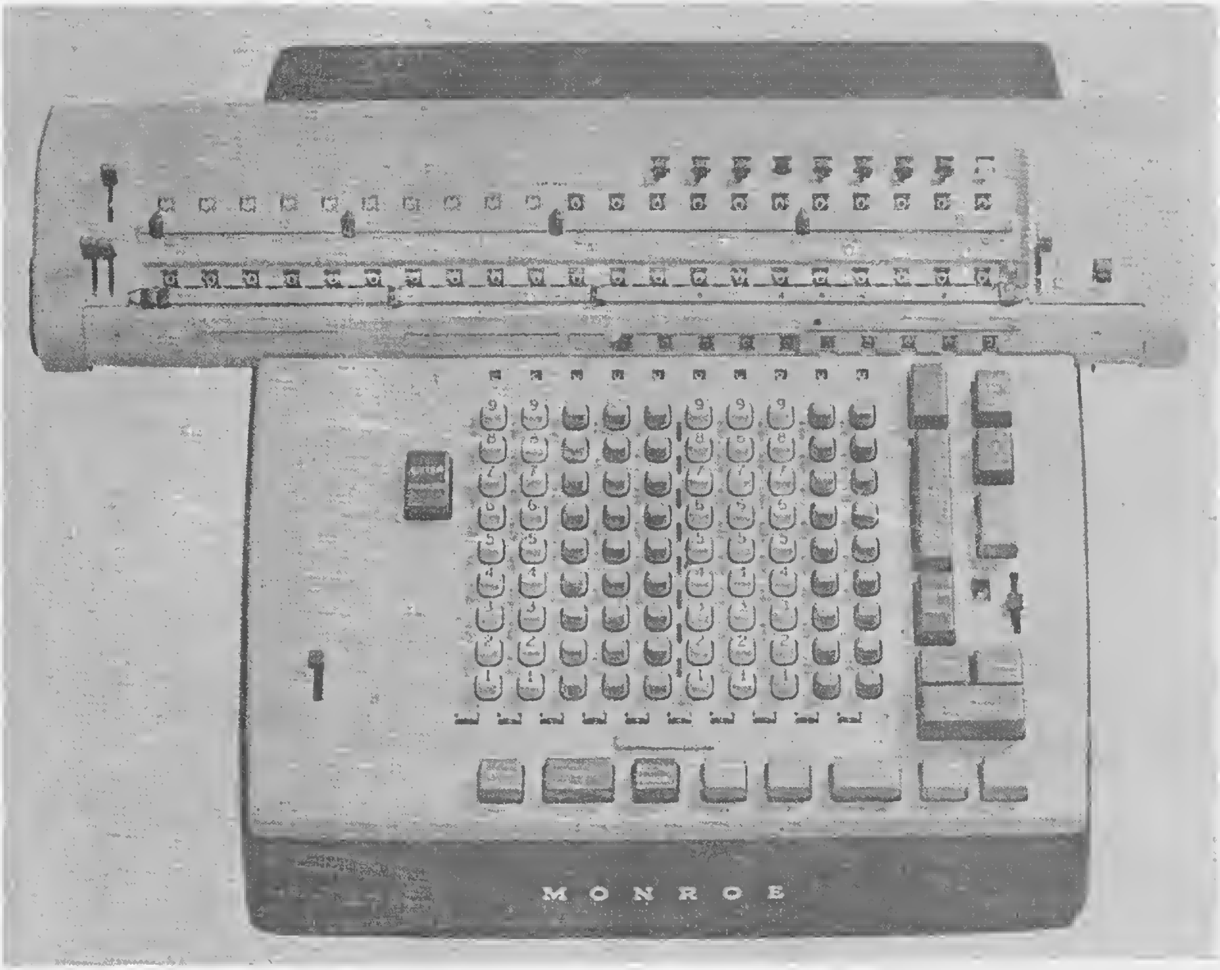
CONTROLS

1. Product to keyboard lever (PROD TO KB)
2. Fraction blockout slide
3. Full keyboard hold key (KB HOLD)
4. Automatic decimal control lever (AUTO DEC)
5. Decimal point key
6. Decimal knob
7. Multiply and square key (MULT SQ)
8. Accumulative multiply and accumulative square key (ACCUM MULT SQ)
9. Negative multiply and negative square key (NEG MULT SQ)
10. Multiply clear key (MULT CLEAR)
11. Repeat Lever (MULT REP)
12. Non-entry lever (NON ENT)
13. Three-way counter control lever (CTR CON)
14. Enter dividend key (ENTER DIVD)
15. Positive divide key (÷)
16. Negative divide key (÷)
17. Selective tabulator stops
18. Plus bar (+)
19. Minus bar (—)
20. Keyboard clear key (KB CLEAR)
21. Carriage clear key (CARR CLEAR)
22. Right shift key (• ►)
23. left shift key (◄ •)
24. Keyboard lock lever (KB LOCK)
25. Division stop lever (DIV STOP)
26. Keyboard repeat lever (KB REP)
27. Column clear and lock keys
28. Lower counter dials clear and lock
29. Right upper dials clear and lock
30. Left upper dials lock
31. Upper dial twirlers
32. Fractional cent dial in 8th position
33. Controls interlocked to prevent mis-operation

OTHER FEATURES

1. Exclusive 10-key multiplier keyboard with visible check dials
2. Full keyboard for multiplicand, addition, subtraction, division, and squaring
3. Automatic short-cut multiplication (positive, negative, or accumulative)
4. Automatic multiplier decimal
5. Counter dials on carriage
6. Overflow counter dial
7. Automatic squaring (individual answers or algebraic accumulations)
8. Automatic direct tabulation
9. Automatic touch-one-key division (positive or negative) with automatic decimal point
10. Automatic divisor alignment
11. Automatic over-capacity division lock (21st dial)
12. Single-cycle addition and subtraction
13. Single-cycle repeat addition and subtraction
14. Continuous cycle addition and subtraction (for semi-automatic multiplication)
15. Single-cycle back transfer
16. Full keyboard decimal markers
17. Decimal markers on multiplier, upper, and lower dials
18. Indicator for active counter dial
19. Upper dials split indicator
20. Overload circuit breaker
21. One-way mechanism
22. Non-glare neutral color
23. Non-glare two-tone keys and controls
24. Built-in desk pad
25. 90-125 volt, AC-DC, 25-60 cycle, 100 watt motor
26. 12' cord and dust cover

	SVJ
Full keyboard columns	**10**
10-key multiplier dials	**10**
Lower counter dials	**11**
Upper product dials	**21**
Weight	**56 lbs.**
Domestic shipping weight (approx.)	**68 lbs.**
Export shipping weight (approx.)	**73 lbs.**
Export shipping volume	**4.4 cu. ft.**



This is the calculator with a memory. It is the most automatic ever produced and goes straight to the answer in the most direct way. In practical day-to-day work, it reduces computational activity to simple push-button procedures.

For the first time on any machine, a constant divisor can be recalled from the Memory with a touch of a single button, eliminating the necessity of using reciprocals on most problems. Ten digit constants can be stored in the machine and recalled over and over again. And because the IQ–213 automatically programs itself for every calculation, there's no need to position the carriage, clear the keyboard, move levers or set zeros when changing from one arithmetic sequence to another. When working with dollars and cents, the answer is rounded off to the nearest whole penny automatically.

Experts who have used the IQ-213 call it the ultimate in desk calculating machines since it has the ability to solve problems with greater speed and fewer operator decisions than any previous calculator. It's compact enough to be used on your desk and still leave you ample work space for all the other necessities of office life.

You will like this Monroe because it is the easiest calculator to operate. Most of the physical handling of intermediate figures usually necessary on ordinary calculators is eliminated. When extending 3 factors such as units, weight and price, each figure can be loaded into the machine before the first multiplication takes place. Then by merely pressing the operational buttons, the problem unravels in one continuous action. The operator is free to concentrate on the work itself, letting the machine handle the mechanical aspect of each problem.

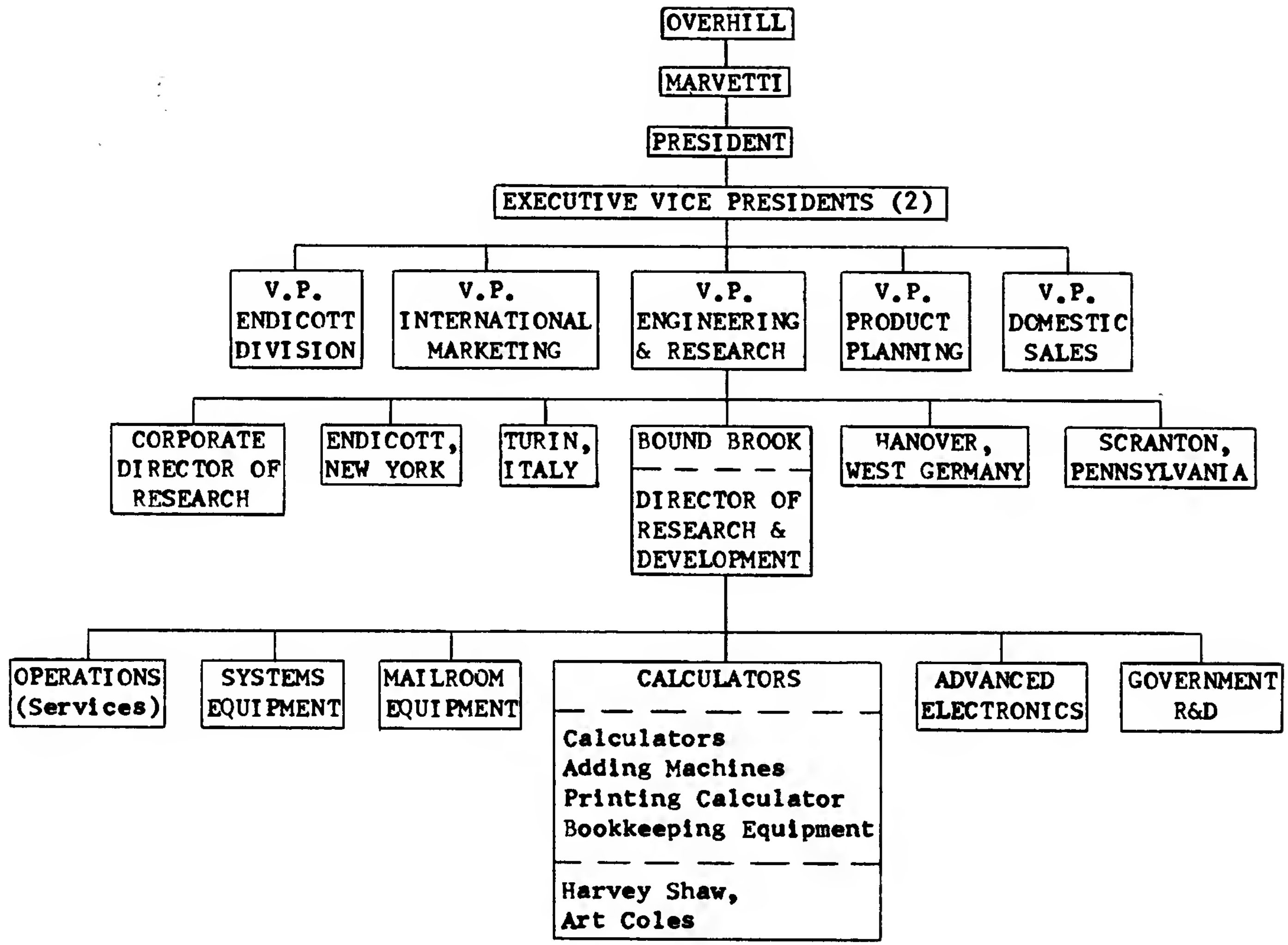


Exhibit 2: Marvetti R&D Organization Chart (1960).

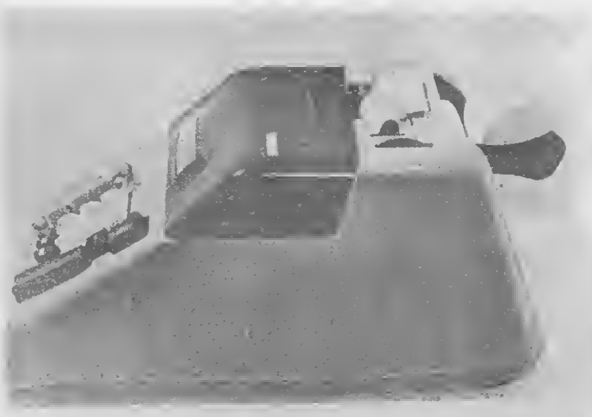


Exhibit 3: Adding Machines.

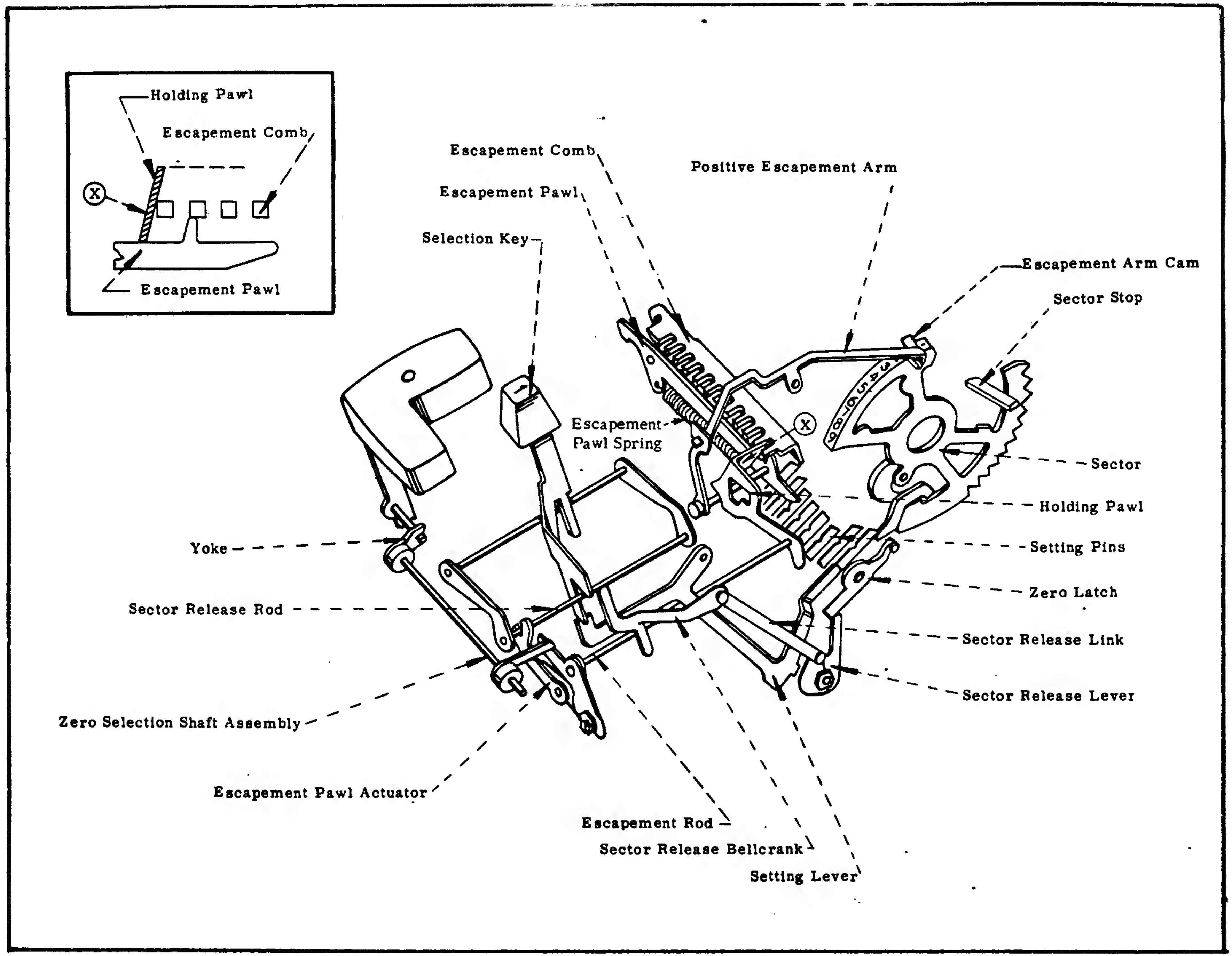


Exhibit 4: A Portion of the Selection Mechanism.

MARVETTI, INC. (B)

Design and Development of a Printing Calculator

Product Testing Program

The engineers in the Research and Development Department at Marvetti have facilities available to them for performing engineering tests on equipment under development, but approval tests on prototype machines are carried out in the Product Test Laboratory, which is not under engineering control. The laboratory is responsible to management and not to R & D because management believes such a separation between engineering and test functions results in higher quality products. Since the establishment of the Product Planning Department in 1956 this department has operated the Product Test Laboratory. There was no group formally charged with product planning until this time.

Calculators may have as many as 10,000 parts, therefore only overall machine performance is checked during the tests run in the Product Test Laboratory. In the test lab machines are operated by hand or by automatic "robots" which use solenoids to punch the keys. Ordinary numerical computations are performed. In general these are problems with large numbers so that the machine's capabilities are fully tested.

When a machine gives a wrong answer while on test, malfunctions in some other way, or suffers part failures, servicemen or engineers attempt to find and correct the trouble. Complete records are kept of all such occurrences and a continuous record of the principal test criterion -- mean time between failures (MTBF) -- is obtained. MTBF is the time which is obtained when cumulative operating hours (in terms of clock time, not drive motor time) to the time of the latest failure are divided by the cumulative number of failures.

There are three categories of tests, designated by the letters "A", "B" and "C":

"A" tests -- These are tests run on hand built engineering models, which may be complete machines or incomplete but operable assemblies (for instance, the first printing calculator to be put on "A" test contained only addition and subtraction capabilities). Test results are reported only to R & D and the conduct of the test remains under their control. In general, the object of the "A" test is to determine whether a machine performs a certain function satisfactorily -- the machine may be tested for wear, life, accuracy, etc.

"B" tests -- These tests are run on complete hand-built prototypes. Test criteria, including the problems to be run, are formally prepared by Product Planning. "B" test results go to management and form the basis for decisions on whether to begin tooling the machine for production. Prior to the creation of the Product Planning Department test specifications were written by R & D in conjunction with the Sales Department.

"C" tests -- "C" tests are run on machines built with production tooling during pilot production. The test procedure is normally identical to that for the "B" test. Management decisions on when to release a machine for full scale production and sale are based on "C" test results.

The test operators also evaluate the machine for ease and comfort of operation during "B" and "C" tests. While costs of "A" and "B" tests are charged to the machine project, "C" tests are charged to the Manufacturing Department. Field tests normally follow and parallel the "C" tests.

The test operators record operator hours and failures (also wrong answers, etc.) on the forms shown in Exhibit 1. These test lab log sheets cover two days of the "C" test of a printing calculator during July 1960. When wrong answers are obtained the printed tape is retained in the log. Details of failures as uncovered by the servicemen are transferred to Service Record forms, shown in Exhibit 2 for the same period as the log sheets, copies of which go to the R & D and Service Departments. Once each week, up-to-date copies of the Product Test Log, shown in Exhibit 3, are prepared and submitted to management. A complete record of the performance of each test machine is available on these; they serve as progress reports and are the basis for management decisions. The MTBF numbers which appear in Product Test Logs are not very closely related to expected time between failures for machines in the hands of customers. The usage of test machines is much more severe, since the operators work the machines continuously, and the MTBF's in customer service may be greater by as much as a factor of ten.

Continual improvement and debugging of the machine by engineering personnel from R & D goes on during all three phases of testing. During "B" and "C" testing, R & D personnel may observe tests or rely upon reports and information from the servicemen to call problem areas to their attention. Since "B" tests are quite severe, several prototypes are commonly built and the design debugged and refined before R & D has a machine they think performs well enough to be put on "B" test. It may take many iterative test/redesign loops before a machine passes the "B" tests; however, once test criteria are fixed, every effort is made to design a machine that will meet them, rather than change the criteria. "B" tests commonly take from two to eight months to complete. At times, however, because of competitive pressures within the industry, a conditional release for tooling may be issued before a product has passed the "B" tests. This will allow the factory to order those tools and gauges having the longest lead times. Generally one to two years are needed to tool up for a new machine.

Because of the complexity of calculators and the many parts they contain, all of which must perform satisfactorily, product design and development periods run from about two years to about nine years, with the most common time being four to five years.

From two to fifty machines may be put on "C" test before a product is determined acceptable for sale. Again, "C" tests usually take several months, and changes to both the design of the machine and the tooling are commonly made. Inexperienced assembly personnel are also a common cause of trouble with "C" test machines. Occasionally, if the performance of early "C" test machines appears satisfactory, a machine may be released for full scale production and sale before completion of the "C" tests.

Before a machine receives final approval it must also pass vibration tests, operating tests after exposure to temperatures ranging from -35° to 140°F., and salt spray, abrasion, and scratch tests on painted or plated parts. Further, and more severe, vibration tests are performed on machines packed in shipping containers.

Packaged machines are also subjected to various drop tests. Before a machine is sold in the U.S., it must pass the Underwriter's Laboratory tests and certain models must also pass the Electronic Interference Elimination tests of the federal government purchasing agencies.

Printing Calculator Development, Continued

The first thing Harvey Shaw did upon being named Project Engineer on the printing calculator in September, 1953, was to investigate the characteristics of competitive printing calculators. He compiled a list of their features as an aid in establishing design criteria for the Marvetti calculator.

It was felt that parts and tools already existing for the adding machines should be used to as great an extent as possible. Mr. Shaw also planned to rely heavily upon the engineering experience gained during the development of the adding machine. Work was to proceed on only one basic printing calculator -- a conventional model aimed at the approximate performance level of the best of the competition.

During the rest of 1953, Mr. Shaw gathered together a group of engineers and designers to work on the printing calculator and preliminary design work was begun. Space was allocated within the machine for the various functions which had to be accomodated, including the motor with its gears, clutches and shafts, the keyboard and number selection mechanisms, the accumulator -- in which results of the arithmetic operations are stored prior to printing of totals or subtotals -- the printer itself, and the add/subtract, multiply, and divide mechanisms.

In general numbers are stored and manipulated as positions of gears; for instance, the accumulator of the printing calculator can store numbers of up to thirteen digits in the thirteen identical sets of gears called "orders" or "registers." Each of the orders contains an accumulator gear with an attached transfer cam, as shown in Exhibit 4. The transfer cam is fixed with respect to the gear. A number, say +4, entered into the accumulator gear through the accumulator feed gear results in a rotation of the accumulator gear by four teeth in the positive direction from the reference provided by the transfer cam. If a +9 is in the accumulator and a +1 is added to it, the transfer cam will actuate mechanisms resulting in a transfer of the first digit of the result to the next order.

A greater portion of the accumulator is shown in Exhibit 5. Numbers are entered through the actuator gear in the upper left hand corner. They are transferred to the accumulator gear through the rear pendant gears. The shaft and gears mounted in the feed gear carrier may be in either of two possible positions -- meshed with the lower of the three rear pendant gears, as shown in Exhibit 5, or meshed with the middle rear pendant gear. Entries to the accumulator gear through the middle pendant gear rotate the accumulator gear in the positive direction, those through the lower gear rotate it in the negative direction.

Mr. Shaw described the process of designing the calculator as, basically, designing mechanisms to put into effect logical concepts. The manipulations of numbers which the calculator must carry out are well defined. The design problem consists of developing reliable ways to accomplish them at high speeds. Mr. Shaw said that the approach he took was to first make a logic diagram, or flow chart, of the operations to be accomplished -- then synthesize mechanisms to carry them out. The design and perfection of cams, gear trains and linkages is the time consuming part of the project.

Among the parts carried over to the printing calculator from the adding machine were the keyboard entry mechanisms and check dials, the printer, and most of the actuator mechanism, shown in Exhibit 6, which transfers numbers to the pendant gears and accumulator. Many parts of the accumulator are also the same as those on the adding machine; however, the accumulator of the printing calculator has more registers. While the accumulator on the adding machine uses two pendants, one for entries of each sign, the printing calculator, as explained previously, uses only one. The motor and clutch of the two machines are also similar but not identical.

The printing calculator was designed before Marvetti had a digital computer and most mechanism synthesis was accomplished without the aid of the techniques which are being used in the design of newer machines. For example, linkage proportions were commonly determined graphically or by trial and error. The cams used were mostly of the constant acceleration, simple harmonic or cycloidal varieties -- which can be synthesized relatively easily without a computer. Typical cams used in a printing calculator appear in Exhibit 7.

Mr. Shaw pointed out that even using the computer it is not possible to analyze the mechanisms in a calculator dynamically. One of the problems is that loads, deflections and motions are different for different computations; there are 13^{13} different operations possible on a machine with 13 registers. It is obviously impossible to test and check all. Mr. Shaw recalled that it was not discovered that an early adding machine would fail on one particular computation until almost a thousand machines had been sold. A purchaser brought the matter to the company's attention. It was necessary to make a small modification to one of the operating cams and to incorporate it in all existing machines.

Similarly, only a few of the most critical parts of the printing calculator (about 5% to 10%) were analyzed for stresses -- the sizes of the rest were determined on the basis of the designers' experience. On many parts loads are only a few ounces, but they must be large enough to take loads of tens of pounds during manufacturing. Stress analysis has recently become more important in calculator design. Lighter parts are

desirable to decrease noise and increase operating speed by reducing inertia. The contact stresses on all cams and followers used in the printing calculator were determined and the parts designed accordingly using the Hertz equations.

The procedure Mr. Shaw and his design group followed when they began work on the functional parts of the printing calculator was first to build and develop a prototype machine capable only of addition and subtraction. The design development and "A" testing of this prototype continued through 1954, 1955 and into 1956. There were an average of 8 to 10 men on the project during most of this period, and through 1957. All parts of this machine, and of all prototype machines built during the printing calculator development project, were made by the engineering model shop from completely detailed drawings. Mr. Shaw stated that all drawings made were suitable for release to manufacturing for tooling. When hand built parts could not be made to precisely simulate tool-made parts -- as in the cases of injection molded plastic parts or powdered metal parts -- the tooling was obtained and the parts made from it. By June, 1956, the machine containing only add/subtract capability had successfully completed the "A" level of tests.

Beginning in the middle of 1954, a prototype including multiplication as well as addition and subtraction was built and "A" tests begun.

A complete package incorporating addition, subtraction, multiplication and division was developed and placed on "A" test beginning in the middle of 1955.

A schedule for the printing calculator prepared by Mr. Shaw in September, 1955, is shown in Exhibit 8. At no time during the development of the printing calculator was the project budgeted.

During this period there were no formal design specifications for the printing calculator and this lack resulted in a certain amount of lost time and effort as design goals became matters for discussion. Mr. Shaw said that often their progress would be slowed when some member of management would propose, for example, that the key strokes be shortened, or their touch lightened.

As an example of a typical development problem occurring while the printing calculator was on "A" test, Mr. Shaw pointed to recurrent breakage at the loop of a spring. A check of the calculations established that the spring was properly designed. Further investigation showed that one of the spring winding machines was putting an excessively sharp bend in the wire at one end of the coil, resulting in a significant and unexpected increase in stress.

In the middle of 1956, when a complete prototype printing calculator was on "A" test, Olivetti was granted a patent on a portion of their printing calculator. A patent attorney discovered the patent while scanning the "Official Gazette" of the U.S. Patent Office. Marvetti's design was found to infringe upon the Olivetti patent and the multiplication mechanism had to be redesigned. The affected mechanism is shown in Exhibit 9. The storage unit sectors are rocked counterclockwise when the multiplier is entered. The use of such sectors was covered by the Olivetti patent. The short cut multipliers were modified in the redesign.

In September, 1956, the newly organized Product Planning Department issued a set of product planning specifications for the printing calculator. Excerpts from these are shown, including revisions made at later dates, in Exhibit 10. At this time the design, including the redesign after the patent difficulties, was almost completed, and only a few changes were made in the machine to bring it to conformance with the specifications.

Several months later the redesigned printing calculator was placed on "B" test. The "B" test specifications are shown in Exhibit 11. The "B" test program, with concomitant debugging and redesigns continued through the summer of 1957. These "B" tests were terminated in October, 1957, and on January 7, 1958, management released the printing calculator to manufacturing for tooling to begin. The process of transmitting drawings, parts lists, and other necessary information on the latest, up-to-date design was then begun.

In the spring of 1957, the Manufacturing Department had been brought into the printing calculator project for the first time. Part drawings were given to Manufacturing by R & D so that a preliminary investigation into the tooling requirements of the machine could begin and the first relatively detailed cost estimates on the printing calculator were made -- estimates of manufacturing cost by the Methods Engineering Section and of tooling cost by the Tool Engineering Section.

Beginning in the fall of 1956, an attempt was made to utilize the critical path PERT technique as an aid to controlling project scheduling. A typical PERT chart used, one dating from September, 1957, appears in Exhibit 12. It was prepared by the manager of the Calculator Section of the R & D Department. Mr. Shaw recalled that, while he held periodic meetings of his group during which they discussed the prospects and probable timing of future engineering work on the calculator, little actual use was made of the PERT charts as a formal aid to planning. He also pointed out that the charts entirely neglected the debugging phase of development.

Exhibit 1: Operator's Test Logs.

EXPERIMENTAL TEST NO. X105202 "C" Test

MACHINE NO. #1275

NOTIFY PHONE

DATE	OPERATOR	START	STOP	TOTAL HOURS	~~CYCLES~~ operations	OPERATING TIME BETWEEN FAILURES	DOWN TIME	Unit/Area Affected	Service Record No.	Running Time Meter # 8250	REMARKS	INITIALS
				Received in test Lab at 2:15 PM. 1-21-60								
7-21-60		0		0	0	0			Info.		7-21-60 Starting "C" Test criteria	
7-21-60	Phyl	4:45 PM		0	0	.0				.0		
			6:30 PM	1.8	1,004	1.8				.6		
7-21-60	BMS	7:00 PM		1.8	1,004	1.8				.6		
			8:30 PM	3.3	2,834	3.3				1.1		
7-21-60	Phyl	9:00 PM		3.3	2,834	3.2				1.1		
			10:00 PM	4.3	3,159	4.3			#1	1.4	Test Pattern #3.4	
						.10					Selected 99 depressed X² Key than	
											Accum = Transfer = simultaneously.	
											Procedure is to select 99 five more times	
											depressing Accum = transfer = after each	
											selection, on 5th selection of 99 depressed	
											Accum = Transfer = and machine printed	

Form No. 410-1 TEST LAB LOG SHEET

EXPERIMENTAL TEST NO. X105202 "C" Test
MACHINE NO. #1275
NOTIFY
PHONE

DATE	OPERATOR	START	STOP	TOTAL HOURS	Operations	OPERATING TIME BETWEEN FAILURES	DOWN TIME	Unit + Area Affected	Service Record No.	Running Time Meter #5250	REMARKS	INITIALS
											incorrect Subtotal.	
											Printed = 9,900,000,000.00 SX	
											Showed Print = 980,100,000,000.00 SX	
7-22-60								Termination Block	#1		7-22-60 CORRECTION: 1054 spring came off stud.	
											Replaced spring over stud and	
											installed #4449 clip in groove to	
											insure against spring coming off as	
											per usage change (#498 authorized	
											by of R & D)	
											NOTE: Also installed 4449 clip on shut	
											cut latch spring [illegible] per same	
											change #498.	
7-22-60	Paula	9:00 AM		4.3	3,159	.0				1.4		
			10:00 AM	5.3	4,458	1.0				1.8		
7-22-60	Marge	10:10 AM		5.3	4,458	1.0				1.8		
			11:40 AM	6.8	5,785	2.5 / .0			#2	2.5	Test Pattern #3.5	
											Machine very hot and slowing	
											down on Multiplication and	
											Division operations. Answers correct.	

Form No. 410-1 TEST LAB LOG SHEET

```
              444,444.44 N  X
              444,444.44    =
   19,753,086,024,691.36 S  X

              444,444.44 N  ÷
              444,444.44 N  ÷
                     .00 T  ÷

              555,555.55 N  X
              555,555.55    =
   30,864,196,913,580.25 S  X

              555,555.55 N  ÷
                     .00 N  ÷
  975,308,641,913,580.24 T  ÷
```

Incorrect quotient & remainder

F #1275

7-22-60 Ser. Rec #3

Test Pattern #3.5

```
                .00 T

                .99 N  X
                .99    =
              98.01 S  X

                .99    =
           9,801.00 S  X

                .99    =
         980,100.00 S  X

                .99    =
      98,010,000.00 S  X

                .99    =
   9,801,000,000.00 S  X

                .99    =
   9,900,000,000.00 S  X
```

7-21-60

Test Pattern

3.4 Page 2

InCorrect Subtotal

Should Print 980,100.000,000.00

Ser. Rec. #1

Page 3 " C" Test

EXPERIMENTAL TEST NO. X 105 202

MACHINE NO. #1275

NOTIFY PHONE

DATE	OPERATOR	START	STOP	TOTAL HOURS	Operations ~~CYCLES~~	OPERATING TIME BETWEEN FAILURES	DOWN TIME	Unit + area affected	Service Record No	Run Time meter #5250	REMARKS	INITIALS
7-22-60				6.8	5,785	.0		Motor	#2	2.5	7-22-60 CORRECTION: Motor overheats	
											Installed latest design motor	
											#215010. Low speed - 160 RPM	
											High Speed - 236 RPM.	
7-22-60	Fordly	12^{00}		6.8	5,785	.0				2.5		
			12^{25} PM	6.9	5,818	.1 .0			#3	2.6	Test Pattern #3.5.	
											Selected X² key, then Accumulator = simultaneously. Sub-	
											Total correct. Selected 8-5's,	
											depressed divide key. Machine	
											printed incorrect quotient +	
											remainder.	
											Printed - 555,555.55N ÷	
											975,308,641,913,580.00N ÷ .24T ÷	
											Should Print - 555,555.55N ÷ 555,555.55N ÷	

Form No. 410 - 1 TEST LAB LOG SHEET

SERVICE RECORD

CODE: Loc. Rec. T#1 — MO. / DAY / YR.: 7/21/60 — MACHINE ~~LOCATION~~ Ft: C

MODEL: — SERIAL NUMBER: 1275 — ~~DEPT.~~: Test

Local Office - (See Telephone Directory)

FOR HOME OFFICE USE ONLY	
INVOICE DATE	INVOICE NUMBER

~~METER~~ ~~ASCENDING COUNTER~~: 4.3 operator Hours — CODES: 3,159 operations — CODES:

FIRM (PRINT) ABBR. OK ☐: Product Test Lab - Job Order — CUSTOMER P.O. NO: X105202

~~ADDRESS~~: Current updated Machine as of 7-21-65 — REQUISITION NO.:

CITY — ZONE — STATE — RELIEF MACHINE:

SPEC. ~~BILLING~~ INST.: Test Pattern #3.4 Page 2

PARTS			AMOUNT
QUAN.	UNIT PRICE	PART #	
SUB TOTAL			

ADDITIONAL PARTS ON REVERSE SIDE

MAINT. INSP.	CURR. INSP.	MAINT. CALL	CURR. CALL	OUT GUAR.	TRIAL	USED	STOCK	RENT	INSTAL.	LEASE	CALL BACK	PROGRAM CHANGE	1 YR. PART GUAR.	SHOP

CAUSE OF TROUBLE: Incorrect Sub Total on multiplication operation. (Unit - Ennunation Block) 1054 spring came off stud.

METHOD OF CORRECTION: 7-21-65 Replaced spring over stud and installed #4449 clip in groove to insure against spring coming off as per usage change #491 authorized by K. Davis of C.V.D. NOTE: Also installed 4449 clip on shutout latch spring groove as per same change #491

CALL REC. DATE — START WORK DATE — TIME — IN SERV. DATE — TIME

X

SERVICE TECHNICIAN — BRANCH NUMBER — CUSTOMER'S SIGNATURE

STATE TAX	
CITY TAX	
TOTAL TRAVEL AND REPAIR TIME ___ HRS. @ $___ 1/4 HRS. @ $___	
POSTAGE EXPRESS	
CAR FARE TOLL	
PARKING	
MILEAGE ___ @ ___	
TOTAL BILLABLE	

FORM 721-3 (REV. 12) S. L. @1

WORK NOT DONE DURING OUR NORMAL WORKING HOURS WILL BE CONSIDERED OVERTIME

THIS IS NOT AN INVOICE

Test Pattern #3.4

Selected 99, depressed X² key then accum=, transfer= simultaneously. Procedure is to select 99, five more times, depressing accum=, transfer=, after each selection. On 5th selection of 99, depressed accum=, transfer=, and machine printed incorrect Sub Total

Printed	Should print
9,909,000,000.00 SX	989,100,000,000.00 SX

Exhibit 2: Service Record Forms as Completed After Investigation of Failures on A "C" Test Printing Calculator During July 1960.

SERVICE RECORD

Dis. Rec. #2 (C R D T E)	MO. / DAY / YR. 7/22/60	MACHINE ~~LOCATION~~ C	Local Office - (See Telephone Directory)
MODEL	SERIAL NUMBER 1275	~~DEPT.~~ Test	CODES 5785 operations / CODES
~~METER~~ 68 operator Hours	~~ASCENDING COUNTER~~		

FOR HOME OFFICE USE ONLY — INVOICE DATE | INVOICE NUMBER

FIRM (PRINT) ABBR. OK ☐ Product Test Lab - Job Order — CUSTOMER P.O. NO X105202

~~ADDRESS~~ updated Production Machine as of — REQUISITION NO. 7-21-60

CITY — ZONE — STATE — RELIEF MACHINE

SPEC. ~~BILLING~~ INST. Test Pattern # 3.5

MAINT. INSP.	GUAR. INSP.	MAINT. CALL	GUAR. CALL	OUT GUAR.	TRIAL	USED	STOCK	RENT	INSTAL.	LEASE	CALL BACK	PROGRAM CHANGE	1 YR. PART GUAR.	SHOP

CAUSE OF TROUBLE Machine very hot - slowing down on multiplication and division operations. (unit - motor) motor - overheating

METHOD OF CORRECTION Installed latest design motor #215010. Low speed - 160 R.P.M. High speed 236 R.P.M.

CALL REC. DATE / TIME — START WORK DATE / TIME — IN SERV. DATE / TIME

SERVICE TECHNICIAN — BRANCH NUMBER — X CUSTOMER'S SIGNATURE

FORM 721-3 (REV. 12) S. L.

PARTS QUAN.	UNIT PRICE	PART #	AMOUNT
		SUB TOTAL	

ADDITIONAL PARTS ON REVERSE SIDE

STATE TAX	
CITY TAX	
TOTAL TRAVEL AND REPAIR TIME ____ HRS. @ $____	
/4 HRS. @ $____	
POSTAGE EXPRESS	
CAR FARE TOLL	
PARKING	
MILEAGE ____ @ ____	
TOTAL BILLABLE	

WORK NOT DONE DURING OUR NORMAL WORKING HOURS WILL BE CONSIDERED OVERTIME

THIS IS NOT AN INVOICE

Test Pattern # 3.5

machine very hot and slowing down on multiplication and division operations. answers correct.

ECL 45-B
Exhibit 3

Exhibit 3: Summary Test Log for a "C" Test Printing Calculator During July 1960.

WA = Wrong Answer
NSP = Non-standard Performance

MARVETTI PRODUCTS TEST LOG X105202
Updated Production Machine as 7-21-60

PRODUCT Printing Calculator MODEL ____ SERIAL NO. 1275

1960 Date	OPERATING HOURS Since Last Failure *	OPERATING HOURS Cumulative	FAILURE No.	FAILURE Break-Down	FAILURE Other	MTBF	Operations	TEST CLASS: A B (C) STARTED 7-21-60 PAGE NO. 1
7-21		XXXX 4.3	1		WA	4.3	3,159	Incorrect sub-total on mult. 1054 spring came off stud. Installed #4449 clip in stud groove to prevent spring from coming off as per R&D change. Installed 4449 clip to hold short cut latch spring on stud.
7-22	2.5	XX 6.8	2	+		3.4	5,785	Machine very hot, slowing down. Installed latest design motor #215010 adj. for proper speed.
7-22	.1	6.9	3		WA	2.3	5,818	Incorrect quotient & remainder on div. Taper pin came out of total control cam. Reset pin. Note: Replaced defective front base mount #214056.
7-23	10.3	XXXXXXXXXX 17.2	4		NSP	4.3	13,542	Three zeros appear in check dial after neg. = transfer = operation. Formed ribbon control link away from sector delay mechanism.
8-2	6.9	XXXXXXX 24.1	5		WA	4.8	**	Incorrect sub-total on mult. Screw 2021 backed out of rear mult slide. Replaced screw, spacer, & clip.
8-2	.1	24.2	6		NSP	4.1		Selection carriage failed to restore on mult. Formed carriage restore link to relieve bind.
8-3	1.5	X 25.7						Info. Lubricated & inspected machine. Noted slight wear on termination slide #265654.
8-4	8.2	XXXXXXXX 33.9	7		WA	4.8		Incorrect quotient & remainder on div. (accumulator) Reamed & repinned loose feed gear carrier. Replaced malformed zero block #245010. Note: Feed gear carrier twisted. Unable to correct. R&D please note.
8-6	6.5	XXXXXX 40.4	8		NSP	5.0		Failed to complete operation. Unit - overcapacity slide. Moved overcapacity block. Adj. 59.
8-9	.7	X 41.1	9		NSP	4.5	16,743	Failed to go into neg. = accum. = operation. Termination slide not delatched fully. Formed bail on latch #265893 for more overtravel. This is not a standard adj.
8-9	.1	41.2	10		WA	4.1	16,850	Incorrect total on mult. Replaced weak spring #1402 on mult ratchet pawl detent. Also formed lip on zero key block to correct zero bar not interlocking.
	*X = 1 HR.							** Operational counter being repaired due to failure.

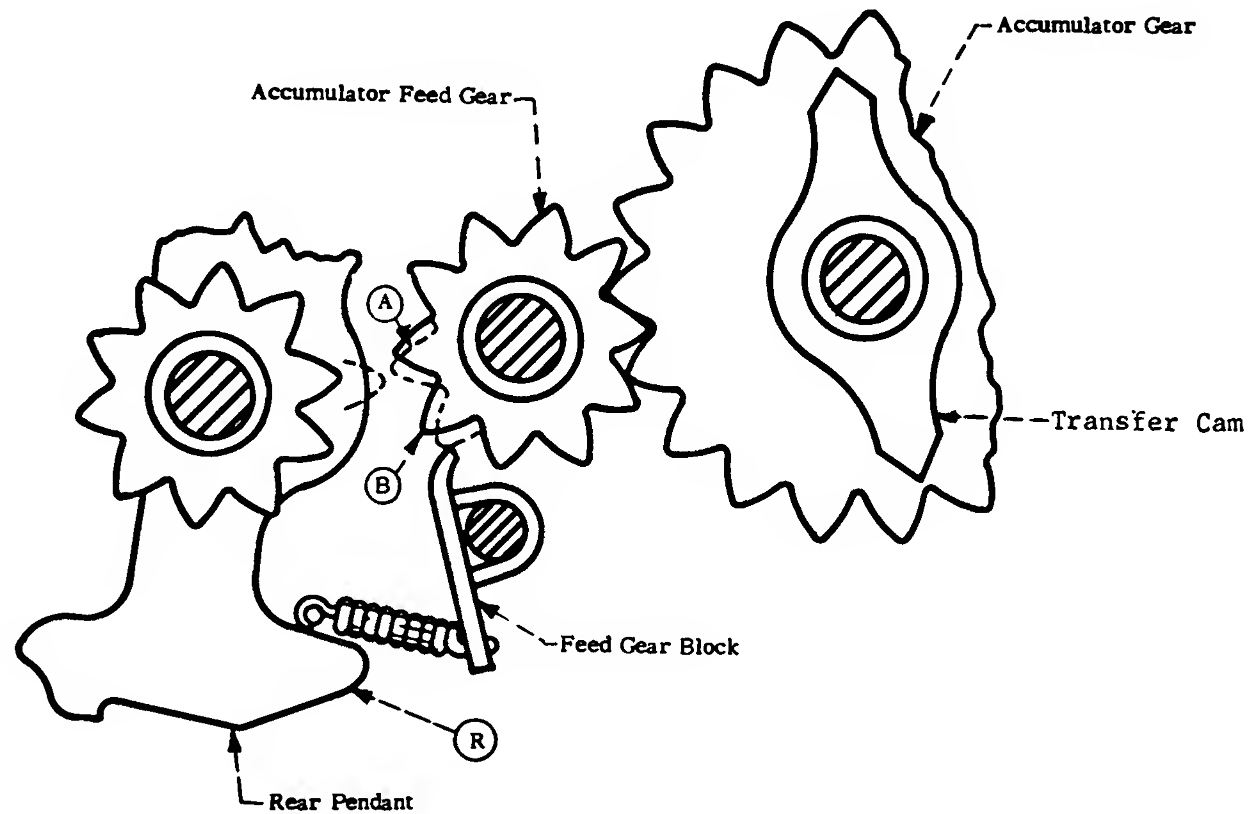


Exhibit 4: Three of the Gears in an Accumulator Register.

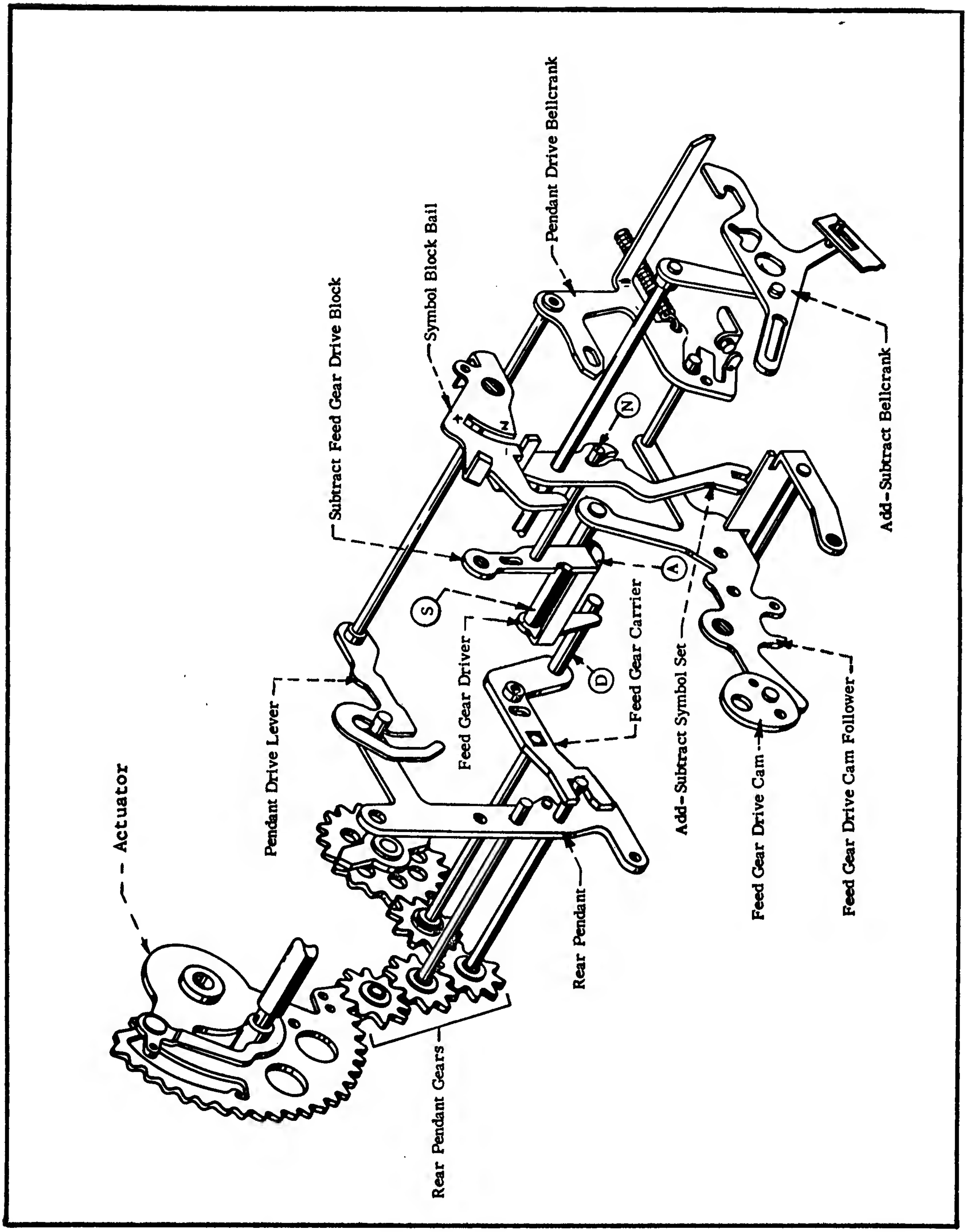


Exhibit 5: A Portion of the Accumulator Mechanism.

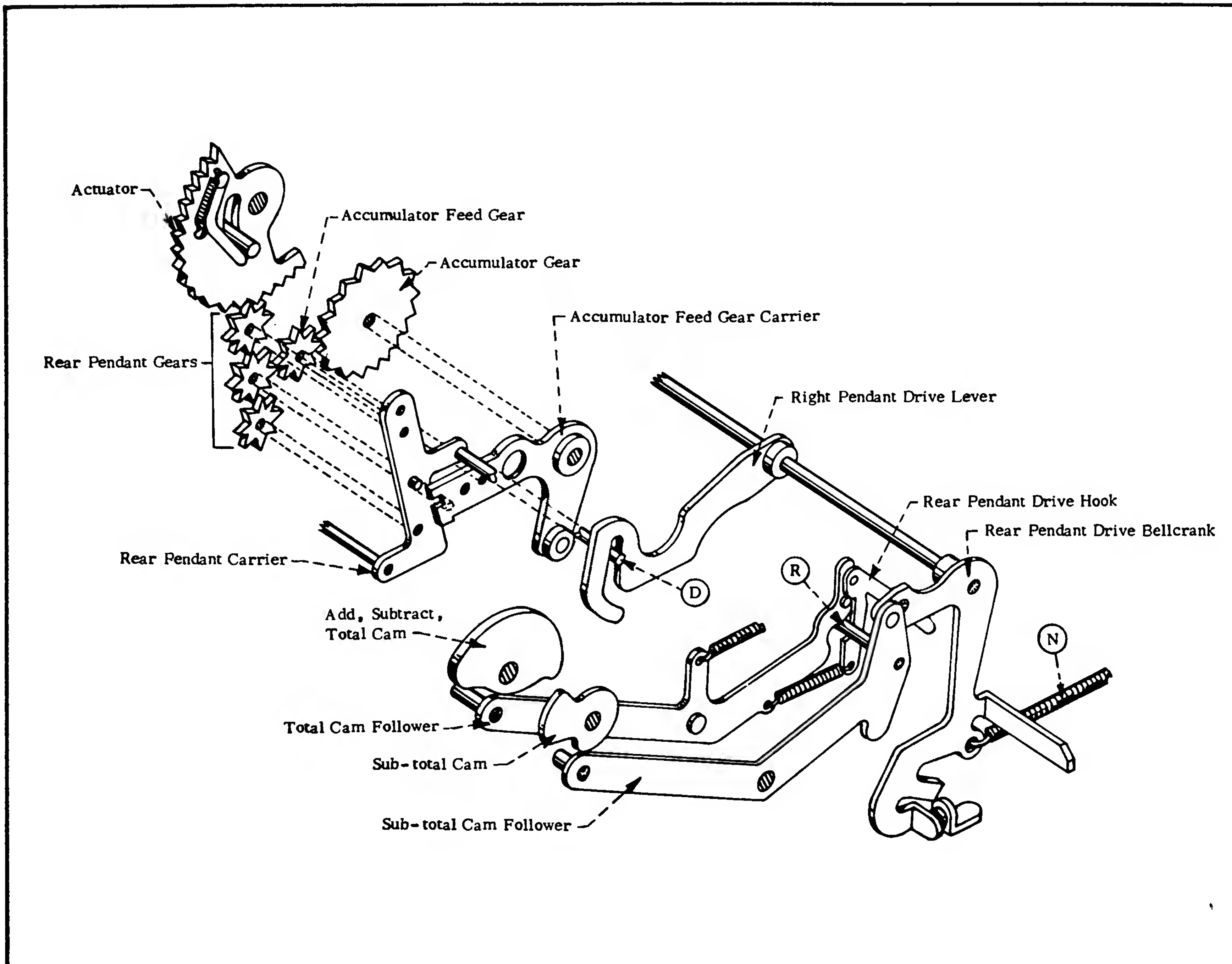


Exhibit 6: A Portion of the Actuator Mechanism.

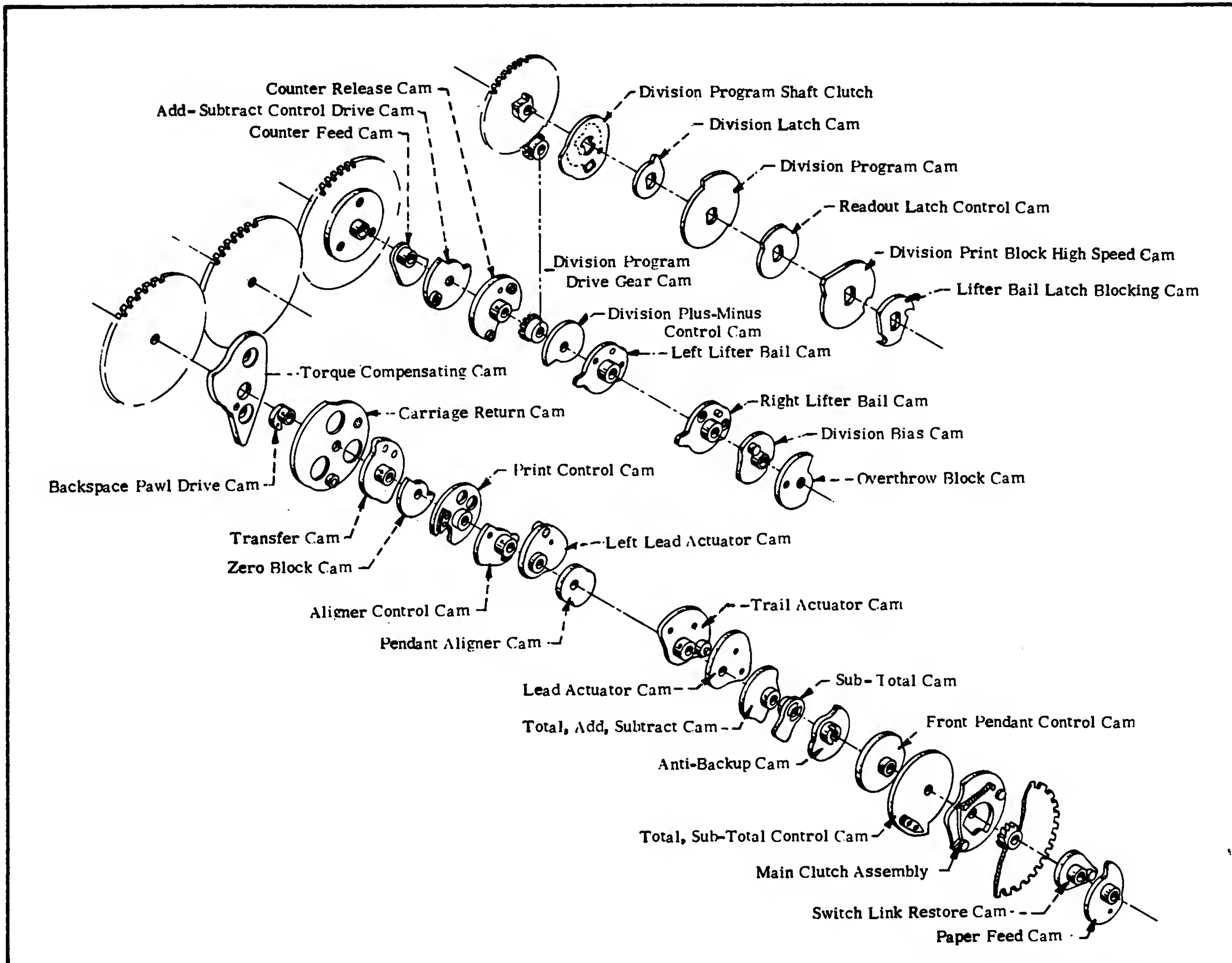


Exhibit 7: Motor Driven Cams Which Control the Operations of the Printing Calculator.

Exhibit 8: Schedule Prepared by Harvey Shaw in September 1955.

PRINTING CALCULATOR (PROJECT No. E-470)

SCHEDULE

Following is a list of Design Classifications, along with the personnel assigned to each classification, and the estimated date of completed installation in a prototype machine:

DESIGN CLASSIFICATION	ASSIGNED TO	ESTIMATED COMPLETION DATE
1. Keyboard controls and interlocks.		
2. Selection unit with positive restore from actuator cams.		
3. Fixed wide platen mounting.		
4. Motor mount for worm drive.		
5. Two speed control of adding machine and printing calculator.		
6. Carriage return and back-space mechanisms.		
7. Redesign of following mechanisms for higher speed digitation and extended capacity:		
A. Actuator control.		
B. Print control.		
C. Zero foil control.		
D. Ribbon drive.		
E. Aligner - new positive drive with overload.		
F. Actuator back-up pawls (possible elimination).		
G. Accumulator detent bail.		
H. Accumulator control.		

I. Back-space.

J. Escapement.

K. Actuator "Sickle" and spring.

8. Multiplication.

   A. Storage matrix entry.

   B. Storage matrix clear.

   C. Sensing of storage matrix and control of multiplication counter.

   D. Sensing of positive or negative amounts for short-cut multiplication.

   E. Sensing of highest significant multiplier digit, for terminating multiplication when zero values remain.

   F. Carriage return of multiplier sensing unit (clutch control).

   G. Automatic total or sub-total when multiplication is terminated.

9. Print suppression during multiplication and division.

10. Division

    A. Study of proposed mechanisms.

11. Decimal point indicator.

12. Over-capacity signal.

13. Symbol controls.

14. Cover design.

15. Base.

16. Frames.

17. Stiffeners.

Division Schedule

1. Keyboard control and interlocks.
2. Sequence control cam (4:1 cam).
3. Division aligner
    a. Accumulator Sensor Finger Control
    b. Carriage Escapement control
    c. Carriage Back-up control
    d. Sense 17 Col dividend
    e. Sense Negative dividend
4. Counter control
5. Counter
6. Add-subtract automatic control from credit balance indicator.
    a. Back-space control
7. Termination of Division Mechanism
    a. Stop Key
    b. Sensing of zero dividend balance in accumulator (double negative of Cr. Bal. Indicator).
    c. Rear carriage back spaces beyond home position.
8. Automatic Quotient (Memory Output)
9. Automatic Total (Remainder)
10. Symbol, print, and motor speed control.
11. Dividend Entry Key - make add connection
12. Redesign Accumulator restore (might involve back-up pawls)

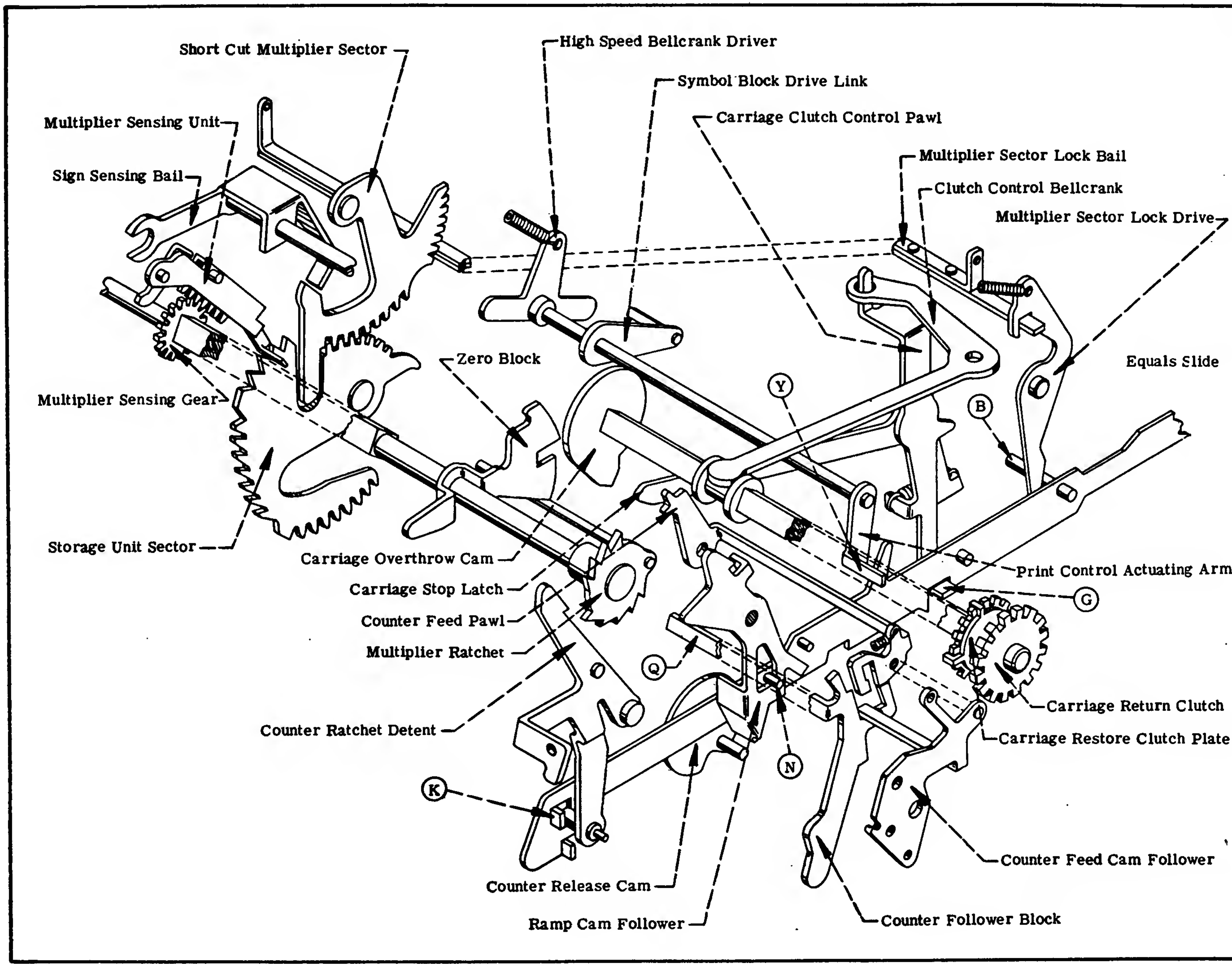


Exhibit 9: A Portion of the Multiplication Mechanism.

Exhibit 10: Excerpts from Product Specifications for the Printing Calculator, Published September 29, 1956, by the Product Planning Department.

1. Purpose

The purpose of these specifications is to define the current status of the printing calculator, and to set down certain changes necessary to bring this product to a state of marketability.

In recognition of the extreme urgency for a product of this nature, no recommendations are included which would involve changes in functional principles or mechanical design, provided the mechanism proves to be reliable.

2. Current Status

2.1 General Properties

2.1.1 Capacity

Addition and Subtraction		12 list, 17 total
Multiplication		
Multiplier and multiplicand combined, up to		16 digits
Product		17 digits
Division		
Dividend		16 digits
Divisor		16 digits
Quotient	up to	16 digits

Note: In instances in which an operation would call for transfer of a 17-digit number to the multiplier register (back transfer or division), such operation is automatically voided and the accumulator is cleared.

2.1.2 Speed - Print and terminal program cycle 150 cpm.

Multiplication and division 235 cpm.

2.1.3 Shortcut multiplication

2.1.4 True credit balance (All subtrahends and credit balances printed in red)

2.1.5 Platen - 3 1/2", fixed

2.1.6 Weight - 35.75 pounds (without covers)

2.2 Functions

<u>Operating Controls</u>

2.2.1 Addition, Subtraction

Print only	Print without accumulating	N
+	Accumulate positively and print	+
-	Accumulate negatively and print	-
Repeat add	By itself, repeat addition	+
	With the minus bar, repeat subtraction	
	With Subtotal or Total, permits printing contents of accumulator without losing keyboard selection	
Subtotal	Clearance of selection, followed by printing of contents of accumulator without clearance of accumulator	S or $\bar{S}$
Total	Clearance of selection, followed by printing of contents of accumulator and clearance of accumulator	T or $\bar{T}$
Clear keyboard	Clearance of selection	none
Back space	Right shift of contents of check dials one position with loss of low order digit	none

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3.4 Reliability

A covered prototype shall be submitted to the Product Planning Department for a Class B Test to consist of the following phases.

3.4.1 A manual operational shakedown of a minimum of 40 hours, with the last 16 hours to be free of error or mechanical failure.

3.4.2 Eight hours of manual operation after each 24 hour environmental exposure to:

3.4.2.1 -35 °F., with prevailing relative humidity

3.4.2.2 140° F., with 95% relative humidity

3.4.3 Eight hours of manual operation under each of the following environmental conditions.

3.4.3.1 35°F., with prevailing relative humidity

3.4.3.2 110°F., with 95% relative humidity.

3.4.3.3 110°F., with 20% relative humidity.

3.4.4 Eight hours of manual operation after subjection to the standard vibration test used for adding and calculating machines.

3.4.5 Eight hours of manual operation after subjection to the standard shock test used for adding and calculating machines.

3.4.6 Automatic robot testing for a minimum of 2,000 hours, clock running time.

Lubrication is to be provided by Research and Development technicians at the start of the 40 hour test and the robot test, and at 85 hour intervals thereafter.

All service shall be performed by Research and Development technicians under the established Test Laboratory logging procedure.

Manual test data shall consist of a series of typical problems involving the various controls worked in rotation. Robot testing shall be divided between various functions during each 85 hour period, approximately as follows:

Addition	35%
Subtraction	5%
Multiplication with: = key	10%
Neg = key	5%
Accum = key	5%
Transfer = key	5%
Neg = and Accum = keys	5%
Neg = and Transfer = keys	5%
Division	25%

The number of failures from any cause shall not exceed the following limits for each phase of the test period:

40 hour shakedown	5
Environmental exposure and operational phases	1 each
Vibration and shock tests	2 each
Robot testing ---	
First ten 85-hour periods	1 each
Eleventh through fifteenth periods	2 each
Subsequent periods	3 each

Exhibit 11: Printing Calculator "B" Test Specifications, Published February 6, 1957 by the Product Planning Department.

1. GENERAL

1.1 Purpose

This test is imposed to establish the following conditions:

(1) That the original product specifications were valid in respect to market requirements and functional utility.
(2) That the prototype representing the end result of the Research and Development activity conforms to these specifications, and
(3) To establish a criteria for use in subsequent evaluation of factory-built units.

1.2 Specific Exclusions

1.2.1 Durability. In recognition of the time involved in life testing and the high investment value of the prototype, no test procedure is specified which would introduce undue hazard. However, any evidence of excessive wear or deterioration observed as a result of this test program may result in prolongation of the test to establish its significance.

It is assumed that life testing will be carried out during the process of development sufficient to satisfy Research and Development that the machine will have a mechanical and operational life equal or superior to a Marvetti adding machine. Further, that, as soon as possible, a machine or machines will be given a full endurance life test to confirm that the machine is satisfactory in this respect. Based on three hours usage per day for ten years, the machine should be able to be manually operated for 7800 hours with normal maintenance provided at 250-hour intervals.

2. EQUIPMENT REQUIREMENTS

Two machines complete with covers and properly lubricated shall be delivered to the Product Planning Department.

3. MATERIALS REQUIRED

3.1 Standard adding machine test data.
3.2 Special calculator test data pertinent to special features provided in the subject model.

4. PERSONNEL REQUIRED

4.1 No fewer than three operators shall participate in each manual operating phase, such operators to be supplied by the Test Laboratory under the normal rotation of staff.
4.2 Research and Development will provide one technician to perform all mechanical service.
4.3 The Service Department will appoint one person to serve as observer of all corrective work.

5. GENERAL INSTRUCTIONS

5.1 The operators shall be instructed to operate the machine at what would be considered an efficient work rate under commercial conditions.
5.2 The operators shall be instructed to make note of any undue fatigue (muscular, optical, etc.) which results from the operation of these machines.
5.3 "Running meter time" shall be measured by the time the motor in the machine is actually running in any normal operation. Where this is not specifically stated, exposure periods and the like shall be measured in regular sun time.
5.4 All variations from standard functions shall be logged. In the event of incorrect answers, sufficient data shall be recorded to permit subsequent analysis or reproduction of the result. In the event of mechanical failure, the Research and Development and the Service Department shall be immediately notified.
5.5 All mechanical service shall be provided by the Research and Development technicians under the observation of the Service Department, or by the Service Department under the direction of Research and Development. No corrections shall be made beyond the tolerances permitted by the adjustment specifications. Any corrections requiring modification or substitution of parts beyond these tolerances shall be referred to the development engineer, and the test program shall be suspended at that point. The decision to resume or terminate the test shall be by agreement between Research and Development, Service, and Product Planning.

6. TEST PROGRAM

The following tests shall be conducted in the order given

6.1 Application Evaluation

This shall consist of an over-all appraisal of the machine from the standpoint of market acceptability. It shall be conducted by the Product Planning Department in cooperation with the Sales Department.

6.2 Shakedown Test

The machines shall be operated under normal Test Laboratory procedures for a minimum of 20 hours running meter time, the last four hours of which shall be free of failure from any nature.

6.3 Environmental Exposure (Temperatures ±5°F., relative humidities,±5%)

Each machine shall be sealed in a plastic bag as used in preparation for shipment. So prepared, it shall be brought to the indicated temperature and allowed to normalize three times. After such triple exposure to each temperature, the plastic bag shall be removed and the machine shall be operated for two hours running meter time.

6.4 Environmental Operational (Temperature ±5°F.,relative humidities,±5%)

6.4.1 Low Temperature. Each machine shall be brought to a temperature of 35°F, with prevailing relative humidity, and held there for a period of four hours. During this period, the machines shall repeatedly be manually operated for five minutes and allowed to rest for ten minutes. The operation shall include the use of all control keys.

6.4.2 High Temperature, High Humidity. Each machine shall be brought ot a temperature of 100°F., with 80% relative humidity, and operated for four hours running meter time.

6.4.3 High Temperature, Low Humidity. Each machine shall be brought to a temperature of 110°F., with 25% relative humidity, and operated for four hours running meter time.

6.5 Sustained Operation

The machines shall be given normal maintenance inspection and lubrication at this point, after which they shall be manually operated for 50 hours running meter time.

6.6 Vibration

The machines shall be packed for domestic shipment and subjected to a standard vibration test as applied to adding machines. At completion of this treatment, the machines shall be operated for two hours running meter time.

6.7 Robot Test

The first machine to complete the preceding program shall be placed under automatic testing and run for 250 hours running meter time. Normal maintenance inspections and lubrication shall be provided every 50 hours, and shall be followed by a routine manual test using all operating controls.

7. CRITERIA

For purposes of evaluation, the results of this test shall be compared to the reliability level requirement states in the original product specifications.

8. REPORTING

8.1 Test Laboratory

The Test Laboratory shall maintain log sheets which provide the following data:

1. Machine serial number
2. Cumulative test time
3. Cumulative operation count
4. Cumulative running meter time
5. Operator's comments
6. Correctionist's comments

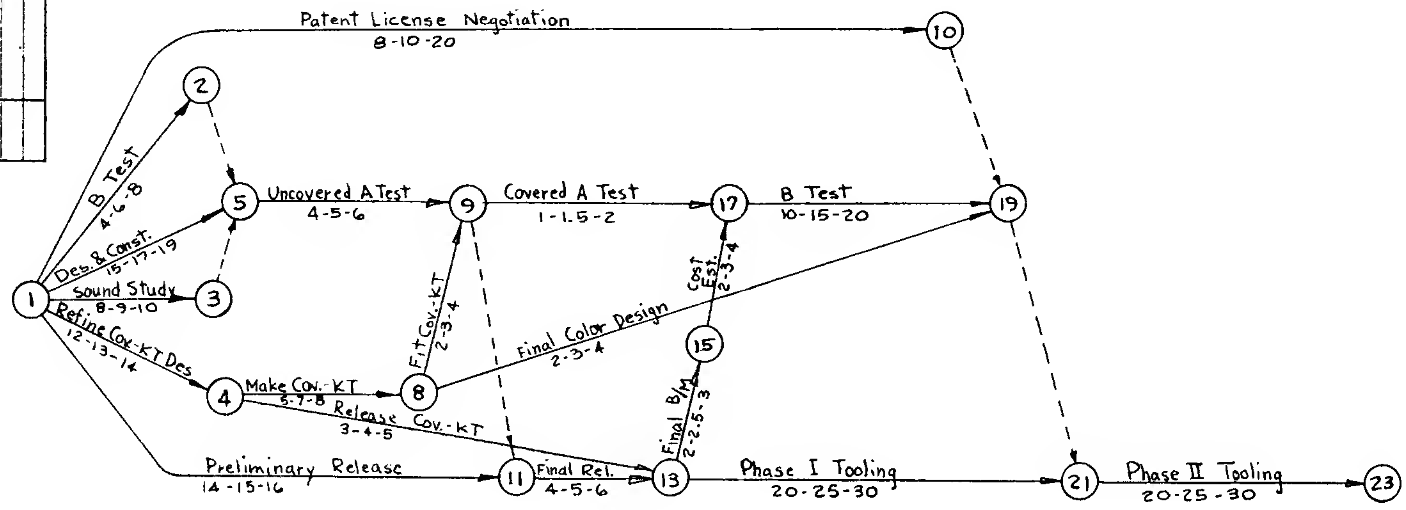
Periodic reports reflecting the progress and results of the test shall be provided the Product Planning, Research and Development, and Service Departments.

8.2 Research and Development Department

The Research and Development Department will provide copies of all service reports to the Product Planning and Service Departments. Any failures requiring other than specified adjustments shall subsequently be reported on as to corrective action taken.

8.3 Product Planning Department

The Product Planning Department will submit reports to Management summarizing the results of the test.



1	Decision to Produce 8/17/57
2	B Test Complete
3	Sound Study Complete
4	Cover Redesign Complete
5	Uncovered Prototype Finished
8	Investment Castings & Keytops Finished
9	Covered Prototype Finished
10	Patent Problem Resolved
11	Initial Release Completed
13	All Released
15	Bill of Materials Finished
17	Presentation
19	Final Acceptance for Production
21	Initial Tooling Complete
23	Start Production

NAME E470 Schedule
DATE 9-10-57

Exhibit 12: PERT Chart Prepared by the Manager of the Calculator Section in September 1957.

MARVETTI, INC. (C)

Design and Development of a Printing Calculator

The printing calculator was to be manufactured in Hanover, West Germany, where Marvetti was constructing a new plant. The decision to expand into Europe was originally made about 1950. The desire for manufacturing facilities in Europe was prompted by the growing market there, by lower labor costs and by the high shipping and duty costs of selling U.S.-made machines abroad. A plant was built in Turin, Italy in the early 1950's for the manufacture of rotary calculators and adding machines. In November, 1957, a furniture factory in Hanover was purchased and adding machine manufacture in the U.S. was also discontinued to allow higher volume production at Hanover. Some systems equipment operations were then transferred to Turin. The new factory being built at Hanover was to provide facilities for both rotary and printing calculators, the plan being to ultimately manufacture only mechanical products at Hanover with the Turin plant reserved for electronic machines.

Ninety per cent of the printing calculator tooling was made in Europe. The process of releasing the part drawings to the Manufacturing Department continued through 1958. In the late summer of 1958, tooling began. It continued until the fall of 1959.

The status and expectations for the printing calculator project in 1958, including information on the prototype machines already built, is well documented in the Master Planning Schedule, issued March 15, 1958, and shown in Exhibit 1.

Efforts by R & D to improve the machine continued during the tooling period. While the number of engineers and designers on the project reached a peak of ten in 1957, there were still an average of five during 1958.

Beginning on January 28, 1958, a prototype machine designated No. E-470-4 was placed on "B" test (see page 3 of Exhibit 1). A series of laboratory reports tracing the progress of this test were compiled for management by the Supervisor of the Product Test laboratory. They appear in Exhibits 2 through 6.

INTRODUCTION

Product Planning Specifications, dated 9-29-56, and Revision No. 1 dated 6-8-57, Revision No. 2 dated 6-12-57, and Revision No. 3 dated 1-17-58, constitute the official specification requirements for the new Marvetti Printing Calculator product.

On 1-7-58, the Product Planning authorization was signed and released by management for the design release to manufacturing and production of Marvetti Printing Calculator, as covered by specification No.008, Revisions 1,2, and 3.

The first objective of manufacturing shall be the release for sales distribution of the Printing Calculator, referred to as the De Luxe Model; therefore, this master schedule is planned in the direction of only this Model Printing Calculator. When we have proven our ability to produce an acceptable Printing Calculator, subsequent planning shall then be initiated for other models, plus the Capacity Machine.

Management has requested that we make the Printing Calculator available for sales distribution in the shortest time possible. This Compressed Planning Schedule provides machines for sales by February 3, 1959.

The Master Plan schedules our Hanover, West Germany Plant as the permanent location for assembly, final inspection, packaging, and shipment of this product for world-wide requirements, however, the production prototype machines shall be assembled, debugged, and Class 'C' tested in the Bound Brook Home Plant. The Turin Plant shall be responsible for 85% or more of the production tooling requirements and piece parts fabrication and sub assembly operations in the same ratio. At a later date, after sales distribution of the first units, the Hanover Plant shall become more fully integrated by accepting all of the final assembly and sub assembly operations, plus a large portion of the piece parts fabrication.

The challenge of producing this new Marvetti product for sales distribution within twelve months is complex because the home plant, Italy plant and West Germany plant must have planning and coordination through the entire Master Schedule. Although the difference in physical locations may cause trying intra plant situations, we nevertheless expect to utilize the three-plant operation as an advantage factor in getting the job done in the shortest time possible.

World wide sales of this new Marvetti product is estimated at a future 10,000 units per year.

On the Index Page, individual schedule dates and responsibilities have been fixed. Obviously, slippage in the schedule events cannot be tolerated. Monthly reports shall be devised by, and directed to, the writer for reporting and controlling the status of this Master Plan.

S. Wherry

DESIGN ENGINEERING RELEASE TO MANUFACTURING

On February 1, 1958, drawing releases from R & D to Manufacturing were well under way. This activity is scheduled as follows:

Design Release - Mechanism

Release 95% of drawings for manufacture by March 1, 1958

Release 5% of drawings for manufacture by May 15, 1958 (After Class 'B' Test)

Design Release - Covers

Release 100% of drawings to Manufacturing on, or before, May 15, 1958

Release specifications for prototype (investment type) cover castings before February 20, 1958 (4 sets to be ordered)

Class 'A' Testing on the E-470-4 (uncovered) latest revision Prototype is a continuing effort at this writing.

BASIC PATENT SEARCH

All patent applications have been filed except two minor applications. The remaining two application filings are scheduled for completion by September 3, 1958.

PROTOTYPE MODELS

The status of the R & D Prototypes, completed and scheduled for completion, is as follows:

Complete Schedule	Machine No. Identification	Application
Completed	E-470-1	E-470-1, originally called the PCM, contains multiplication only and is used to confirm that part of the mechanism. This machine should be considered a partial machine and is obsolete.
Completed	E-470-2	E-470-2 is an engineering model, complete with multiplication and division, but utilizing early mechanisms which are different from those to be used in the final product.

Complete Schedule	Machine No. Identification	Application
Completed	E-470-3	E-470-3 is a covered Prototype. This machine was shown to management in August, 1957, and provided the basis for a decision to release a Printing Calculator to Production, as directed by Mr. Record's memorandum of August 16, 1957. "B" Test on this machine has been completed through the environmental exposure phase.
Completed	E-470-4	E-470-4 is an uncovered exact Prototype and it is now being released for production. This machine has been subjected to considerable "A" testing. It is designated as the Prototype to be formally tested under the "B" Test program.
May 1, 1958	E-470-5	After final assembly, this machine shall be utilized as follows: A. Limited Class "B" Test in Bound Brook until about June 15. B. Air shipped to Turin (Attention C. Burger) for familiarization by Engineering and Production on about August 15. C. Air shipped back to Bound Brook (Attention F. Gordon) for initiation of test equipment design.
May 10, 1958	E-470-6	After final assembly, this machine shall be utilized as follows: A. Limited Class "B" Test in Bound Brook until about June 15. B. Released to Bound Brook Service Department about June 15. C. Released to Commercial Controls Education Center for preparation of Operator's Manual on about October 1.

The final assembly of Prototypes E-470-5 and 6 is expected to start on March 11, 1958. Representatives of both the Bound Brook Service and Production Departments shall work with R & D personnel in the assembly of these machines.

Prototype machines E-470-1, 2, 3, and 4 shall always remain as Engineering reference models. Machines E-470-5 and E-470-6 shall be used for Production references in both the Bound Brook and Turin plants. Also, the machines shall be scheduled so that the Bound Brook Service Department has access to a model for their Master Schedule responsibilities.

Due to the extreme cost of making Prototype Models, we do not plan to schedule any additional requirements at this time.

PRODUCTION AND METHODS ENGINEERING

The Bound Brook and Turin Production and Methods Engineering Departments are scheduled as follows:

FUNCTION	COMPLETION DATE
1. Assign Part Numbers (Bound Brook) The normal four digit series shall be based on minor parts. All other part numbers shall be six digit numbers. The first number shall always be a '2', and the third number shall always be a '5'. It will be necessary to use 105,000 and 106,000 series numbers on studs and hubs, as we have exhausted our four digit series.	95% by March 15 5% by May 15
2. Bills of Material (Revised) (Bound Brook) A Bill of Material was prepared for the Manufacturing Cost Study. This Bill shall be updated by the R & D Division and shall be submitted to Production Engineering by May 1, 1958.	June 15, 1958
3. Parts Drawings (Bound Brook) All design drawings shall be reviewed and redrawn by the Bound Brook Production Engineering Department. All drawing headings shall state "Marvetti-Hanover, Hanover, West Germany", including part drawings for parts to be made or procured under Home Plant control.	Sept. 1, 1958
4. Parts Authorizations (Bound Brook) Bound Brook shall issue Production Engineering authorizations on all Production drawing releases for tooling, including those sent to the Turin Plant. The Bound Brook Production Control Department shall receive copies of the latter.	Sept. 1, 1958
5. Part Operation Masters (Bound Brook and Turin) The Bound Brook and Turin Production Engineering Departments shall produce their own Part Operation Masters (fabrication and assembly instruction data) according to their respective tooling and manufacturing requirements.	Sept. 1, 1958

The ability to meet our Printing Calculator Master Schedule will be largely dependent upon schedule attainment by our Production Engineering functions.

PRODUCTION AND METHODS ENGINEERING - Continued

5. Note: In order to proceed with European production tool procurements by February 1, 1958, it was necessary to initially release design engineering drawings directly to the Turin Plant without the benefit of Production Engineering redraws. These advance Design Engineering drawings will be replaced by Product Engineering drawings. Due to the September 1, 1958, completion schedule date of Production Engineering drawings, it will be necessary for the Turin Plant to work from advance Design Engineering drawings throughout most of the production tool procurement activities.

   Production Engineering must prepare and release their various responsibilities so that long lead tool and fabrication needs are completed first. Simple purchased parts, screw machine parts, etc., can be released in the latter stages of their work schedule.

PRODUCTION TOOL DESIGN AND BUILD (MECHANISM)

It has been estimated that there are 150,000 man hours of tooling required for our first objective Printing Calculator. Further, it is estimated that 37,500 man hours of tool engineering are required. It is estimated that there are 120,000 hours of tooling exclusive of covers.

All tooling on this product shall be essentially Class 'A' and Class 'B' Type tooling* predicated on mass production of 10,000 units per year. Approximately 95% of all tooling requirements shall be sub-contracted to outside shops. Whenever possible, tool design and tool making must be scheduled so that long lead requirements of tooling and fabrication can be released first. All Production Tool Engineering is scheduled for completion by July 1, 1958. Production tool making is scheduled for completion by October 1, 1958.

All tool drawings, including those made and used in the Bound Brook Plant, shall be headed "Marvetti-Hanover, Hanover, West Germany."

The Turin Plant shall be responsible for the tool design and tool making (or sub-contracting) of approximately 95,000 man hours of tooling for the machine mechanism. The subletting of this work was begun on February 1, 1958, by the Turin Purchasing and Tool Engineering Divisions. The Bound Brook Plant is scheduled to release a minimum of 10,000 tool making man hours per week, in the form of part drawings, so that all machine mechanism tooling can be placed within 10 weeks (except the 5% to be released about May 15, 1958, after Class 'B' testing).

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* Classes of tooling refer to the quantities of parts which can normally be produced before the tooling is worn out (Case Writer).

PRODUCTION TOOL DESIGN AND BUILD (MECHANISM) Cont.

In the transfer of part drawings from the Bound Brook Plant to the Turin Plant, an estimated tool engineering form copy shall accompany each part drawing. This form copy, entitled "Marvetti Bound Brook Tool Planning & Estimating for Italy," shall advise the Turin Plant of estimated production type and quantity of each tool and gage needed, plus the estimated tool making man hours for each tool. This information is furnished by the Home Plant in the interests of standardization and economy in the Turin procurement of these tools.

The Bound Brook Plant is scheduled to tool design and provide about 30,000 man hours of tooling. These particular requirements will involve late releases, powdered metal parts, and parts where only Bound Brook machine tools or processes are available, such as plastic parts.

All tooling produced in Europe shall be retained in the Turin or Hanover Plants for production runs. All Bound Brook produced tools shall remain in the Home Plant until the European Plants are in a position to accept same for parts fabrication.

FINAL ASSEMBLY PRE-PRODUCTION STUDY

When E-470-5 and E-470-6 Prototypes began final assembly on March 11,1958, representatives of Bound Brook Production, Service, and R& D engaged in this work in a coordinated learning and familiarization effort.

The Hanover and Turin supervisory personnel will not be indoctrinated into the final assembly operations until the Bound Brook Production Pilot Lot stage is reached. At that time, two employees from the Hanover Plant, and one employee from the Turin Plant, shall learn all assembly operations, adjustments, lubrication points, and inspection phases on the Bound Brook assembly line.

ADJUSTMENT AND LUBRICATION MANUAL

The Bound Brook R& D Department shall write, edit, and publish an Adjustment and Lubrication Manual on, or before, August 1, 1958.

CONSTRUCTION OF NEW HANOVER PLANT

During the period of April 1, 1958, through January 2, 1959, a new Marvetti Plant is to be constructed in Hanover, West Germany. The small plant currently being leased for Adding Machine final assembly is to be vacated when the new plant is ready.

CONSTRUCTION OF NEW HANOVER PLANT-Continued

The new plant is to be constructed on 15 acres of Marvetti property and it will consist of approximately 50,000 square feet of total floor space. The building is to be one story of steel frame and panel construction, making it easily extendable if additional space is required in the future.

Weather permitting, ground breaking is expected in early April, with plant completion by the end of 1958.

PRODUCTION GAGES

During the Production Tooling and Production Engineering phases, we must give consideration to production gage requirements so that the proper special gages are available when needed. The Bound Brook and Turin Quality Control Divisions must coordinate with their respective Tool Engineering and Production Engineering divisions in the study and determination of special gage requirements.

Bound Brook shall be responsible for the special gages required on parts and assemblies to be produced in its plant. Also, they shall provide the final assembly special gage requirements essential to the Bound Brook Production Pilot Lot (to be transferred to Hanover after Bound Brook use.)

Turin shall be responsible for special gages required on parts and assemblies to be produced in the Turin or Hanover Plants. Also, they shall provide the Hanover Plant final assembly mass production gage requirements.

The determination, design, and completion of special gages is scheduled for the completion date of July 1, 1958, for parts and assembly gages, and October 1, 1958, for final assembly gages. Although as much preplanning as possible must be exerted on gages, it is recognized that many gages will be found necessary only after production processes begin.

PRODUCTION TOOL DESIGN AND BUILD (COVERS)

All production tooling is considered as "critical path" activity in the Master Planning Schedule, and the external portion of the machine (covers, keytops, etc.) are no exception. It is, therefore, imperative that our Industrial Design Division release these particular part drawings on May 15, 1958, as promised, so that the Turin Plant can complete the tooling requirements within five months. The cover and exterior parts tooling is scheduled for completion by November 15, 1958.

It is roughly estimated, at this writing, that there are 25,000 tooling hours for the covers and exterior parts, exclusive of the plastic key tops.

CLASS 'B' LABORATORY TESTING

Class 'B' Testing of the E-470-3 revision was completed through the environmental exposure phase. Tests on this revision Prototype satisfactorily proved the basic mechanism.

Intermittent and limited Class 'B' (uncovered) testing has been conducted on the E-470-4 Prototype. Completion of this Class 'B' (covered) test is planned for July 19, 1958, except for the total 2,000 minimum hours of Robot Test time required.

Prototype Models E-470-5 and E-470-6 shall be assigned to operational phase tests as soon as these machines are final assembled.

CLASS 'C' LABORATORY TEST SPECIFICATIONS

On September 29, 1956, Product Planning released the Class 'B' Laboratory Test specifications. There have been no changes made to this criterion in actual application to date.

The Class 'C' Test specifications shall be released by Product Planning on, or before, August 1, 1958.

PRODUCTION TEST EQUIPMENT

The Bound Brook Manufacturing Division shall study, design, and build the Printing Calculator Test Equipment. This equipment shall be transferred to the Hanover Plant when the Bound Brook Production Pilot Lot phase has been completed.

The main test unit required is a Robot-type tester to be used as a final assembly aid. Tentatively, it is planned that three four-station units shall be built with special Marvetti Punch Tape Readers to control the test program, however, the possibility of using an electro-mechanical or solid state electronic device shall be considered.

The design of this equipment should begin on June 3, 1958, in order to have automatic test equipment by December 1, 1958, for the Production Pilot Lot.

PRODUCTION CONTROL

The Hanover and Bound Brook Production Control Departments must exercise exact coordinated controls between the Turin, Hanover and Bound Brook Plants in the execution of this Master Schedule. (The Hanover Plant is not expected to have a separate Production Control function until Hanover mass production begins.)

PRODUCTION CONTROL - Continued

Bound Brook Production Control must order enough parts from the Turin Plant to support the Bound Brook final assembly Production Pilot Lot. Also, they must provide the parts to be produced in the Bound Brook Plant for Bound Brook assembly requirements, as well as those of the Hanover and Turin Plants. Turin Production Control must provide the 95%, or so, total parts required for the Bound Brook Pilot Lot, as well as the assembly requirements of both the Hanover and Turin Plants.

Both Production Control Divisions must exercise tight control of engineering changes, rejections, part replacements, etc. Fast action will be mandatory at all times.

During the interplant exchange of parts preceding mass production, air (instead of sea) transportation will be necessary. All interplant requests for parts must be ordered 8 weeks, or more, in advance of the air ship date.

The following is a breakdown of parts on the new Printing Calculator:

Type Part	New Parts To Make or Buy	Parts From Present Stock	Total Parts Required
Purchased	32	101	133
Piece	929	805	1734
Sub or Major Assemblies	421	111	532
	1382	1017	2399

Economic lot quantities, based on Production Control equations, shall be ordered commensurate with scheduled needs and lead times, however, on initial order for production quantities from production tools, the order quantities shall not be more than is required for the following machines, or usage multiples (Order smaller quantities when deemed prudent):

1. Order parts for 300 machines on Class 'A' type parts (where manufacturing cost exceeds 50¢ each).
2. Order parts for 500 machines on Class 'B' type parts (where manufacturing cost is less than 50¢ each, but more than 5¢ each).
3. Order parts for 1,000 machines on Class 'C' type parts (where manufacturing cost is less than 5¢ each).

Raw materials must be ordered for Turin and Bound Brook parts fabrication beginning April 1, so that all materials are in stock to support approximately 1,000 machines, or less, depending upon cost and lead time, by September 3.

Turin Production Control may experience difficulty in obtaining new raw material requirements because of the long lead time involved on European procurements. They should contact Bound Brook for possible assistance in these cases.

PRODUCTION CONTROL - Continued

Fabricated and purchased parts must be ordered and made available in finished parts stores between June 3 and October 1. The respective Production Control Divisions must be knowledgeable of the delivery status on all new production tools so that they can expedite "first things first" and issue production orders as soon as tools are completed and approved by tool inspection.

Sub and Major Assemblies must be processed between September 3 and November 15; therefore, Production Control must be careful in scheduling so that all component parts are fabricated and purchased for completion before parts which go directly to final assembly. Turin shall do all initial sub assemblies (including hot upset riveting) except copper brazing.

SERVICE MANUAL

During the period of June 3, 1958, through January 2, 1959, the Bound Brook Service Department shall write, edit, and publish the basic (English) Service Manual.

One of the R & D Prototypes shall be assigned to the Service Department for this purpose. Also, a representative of the Service Department is to coordinate with R & D and Manufacturing representatives in the final assembly of the last two Prototypes scheduled.

Copies of the Service Manual should be ready for the initial Service Training School (or preliminary copies).

Foreign language conversion and publication of the Service Manual shall be the responsibility of the Turin Plant.

SHIPPING CONTAINERS

The Bound Brook Industrial Design Department shall provide the exterior art work requirements on, or before, October 1, 1958. The Bound Brook Production Engineering Department shall design the container and interior portion of the carton, beginning September 3, 1958. It will not be necessary to have an export type wooden box. Mass production shipments from the Hanover Plant to the States are to be via sea within large seavans. Completed shipping cartons must be available in the Bound Brook Plant by December 1, 1958.

The European Plants shall order their own stock of shipping containers from a European vendor as soon as the Bound Brook Production Engineering specifications are received.

PRODUCTION PILOT LOT - BOUND BROOK PLANT

The Bound Brook Plant shall have the responsibility of producing the Production Pilot Lot. During this period, the Bound Brook R & D and Manufacturing Divisions will be involved in the usual debugging and corrective actions expected when production tooled parts are assembled for the first time. In order to preclude delay factors we must:

1. Have 100% Manufacturing inspection of the Production Pilot Lot parts to be assembled so that there cannot be any question of tolerance, etc., deviation during this assembly process. Turin must 100% inspect parts made.
2. Have our final assembly group leaders well indoctrinated as to the assembly techniques and problems to be expected.
3. Have assembly fixtures, testers, and tools preplanned and awaiting the Production Pilot Lot Assembly.

Although we plan to execute points 1, 2, and 3 to the fullest potential, there will undoubtedly be debugging problems encountered during Pilot Lot assembly which will involve production tool changes. Because of the time factor and remote location of tools, hand-made parts or reworking of existing parts within the Bound Brook Plant should mitigate the problem.

The Production Pilot Lot (185 units) shall be assembled in the sequence and quantity noted:

QUANTITY	MACHINE SERIAL NUMBERS	PURPOSE
5	1263 thru 1267	Class 'C' Test
1	1268	Bound Brook R & D
1	1269	Turin and Hanover
1	1270	UL Laboratory
1	1271	Bound Brook Production Engineering
1	1272	Turin and Hanover
10	1273 thru 1282	Field Test (Bound Brook and Endicott
15	1283 thru 1297	Service and Sales Training
150	1298 thru 1448	Sales Distribution

The Bound Brook Pilot Lot is scheduled to start on October 1, 1958, with completion of the first 35 (assigned) machines by January 2, 1959, and the remainder by April 1, 1959.

PRODUCTION PILOT LOT - HANOVER PLANT

The Turin Plant shall engage in a first quarter 1959 period of training checking, and final assembly indoctrination. Skilled Turin employees who have plant experience on related Marvetti products shall form a nucleus for Hanover supervisory personnel training. The primary objective is to build major assemblies in close parallel to proven initial major assembly operations in the Bound Brook Plant.

PRODUCTION PILOT LOT - HANOVER PLANT - Continued

The Hanover Plant, using initial Turin major assemblies, shall be scheduled to produce 20 Pilot Lot machines during January and February. The 5th, 10th, 15th, and 20th units produced shall be air shipped to the Bound Brook Plant for Class 'C' Test and final inspection line approval before machines can be released for sales distribution from that point.

OPERATOR'S MANUAL

The Operator's Manual shall be written, edited, and published by the Commercial Controls Education Center during the period from October 1, 1958, to January 2, 1959. The Bound Brook Sales Department shall coordinate and assist in the completion of this work so that basic (English) manuals are available before the Production Pilot Lot Schedule.

Foreign language conversion and publication of the Operator's Manual shall be the responsibility of the Turin Plant.

MANUFACTURING COST STUDY

On August 16, 1958, initial Manufacturing Cost Studies were completed on the Printing Calculators. These costs reports clearly reveal that every effort must be made in all pre-production and production work to produce this new Marvetti product as economically as possible. As these Manufacturing Cost Reports are confidential, they cannot be noted in this writing.

A final Cost Study shall be released on about February 1, 1959, by the Bound Brook Cost Accounting section. All standard manufacturing data must be available by October 1, 1958, in order to compute this cost according to normal year end automatic extension methods.

CLASS 'C' LABORATORY TESTING

The Bound Brook Product Planning Department has full jurisdiction and control of the Class 'C' type testing and machines cannot be released for sales distribution until written approval of this product is released.

The Class 'C' Test assures us that the manufactured machines conform to the Product Specifications No.008, the Class 'B' Test Level, and that the machines in general are of the high quality level expected on Marvetti products. The Class 'C' Test is scheduled to begin in December, 1958, on Bound Brook machines, and in February, 1959, on Hanover machines.

Although the field test is a Class 'C' Test phase, we may not necessarily wait until all field testing is completed before releasing machines for sale. The Class 'C' Laboratory Test, however, <u>must</u> be completed before release for sales distribution.

UNDERWRITER'S LABORATORY APPROVAL

One of the Production Pilot Lot models (serial no. 1270) shall be released to the Bound Brook R & D Department for UL listing and approval. During the Class 'B' Testing, R & D shall coordinate with the Product Planning Division so that when this test is concluded, we can be sure of a product that will later be sanctioned by the UL Laboratory without cause for delay.

It is extremely important that all machines released for North American sales distribution have UL approval noted on the voltage rating decalcomania.

SERVICE TRAINING

Tentatively, the initial domestic service schools are planned for January, 1959, or as soon as the Production Pilot Lot machines are available for this purpose.

SALES TRAINING SCHOOL

The first domestic Sales Training School is tentatively planned to begin on January 2, or as soon as the Production Pilot Lot machines are ready for this purpose.

European Sales Training Schools are to be planned at a later date, or about March, 1959.

ADVERTISING

The Bound Brook Advertising Department shall prepare all basic advertising matter for this new product. Introductory advertising of the pamphlet type is to be issued during the first machine releases for sales distribution. National and world-wide advertising is to be released about two months thereafter (following completion of Field Class 'C' Testing and proven ability to provide quality and quantity). Basic work should begin about December 2, 1958, for availability of this literature to the Sales Department by February 3, 1959.

National and world-wide advertising should not be planned for release, according to this schedule, until about May, 1959.

FINAL ASSEMBLY OUTPUT

Although the Bound Brook Plant is scheduled to produce 185 Production Pilot Lot Machines, the final 150 unassigned units can be considered as production output for sales, as reflected below. (The initial 35 assigned Bound Brook Production Pilot machines are planned for November and December output in 1958).

When this new product has been properly debugged in the Bound Brook assembly line and the Class 'C' Test approved (including satisfactory field test reactions), the Bound Brook Plant shall discontinue its final assembly operations and the Hanover Plant shall assume all final assembly output for this product.

The mass production schedule is planned as follows:

MONTH	BOUND BROOK OUTPUT	HANOVER OUTPUT	TOTAL OUTPUT
January, 1959	50*		50
February	50*		50
March	50*	50	100
April	0	100	100
May	0	200	200
June	0	300	300
July	0	400	400
August	0	500	500
September	0	700	700
October	0	900	900
November	0	900	900
December	0	900	900

*Unassigned machines from Bound Brook Pilot Lot production (subject to change)

RELEASE FOR SALES DISTRIBUTION

According to the scheduled plan, the Class 'C' Lab and Field Tests should be of sufficient duration and qualification to allow the release of machines for Sales distribution as follows:

MONTH	DOMESTIC SALES	FOREIGN SALES
February, 1959	50	
March	50	
April	50	50
May	50	50
June	150	50
July	200	100
August	300	100
September	400	100
October	500	200
November	700	200
December	700	200
	3150	1050

JOB ORDER NUMBER SERIES

All R & D material and labor is charged to experimental and developmental job order no. F73E-470.

A separate F68-T job order series shall be released by the Cost Accounting Department for the control of all material and labor on tooling within the United States.

Parts fabrication and sub assembly orders shall be controlled under the existing Adding Machine series.

(Turin and Hanover Plants)

Job order controls shall be set up by these plants in accordance with established procedures so that the accumulated costs of the various activities shall be known at the end of each month.

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Distribution Copies of this Schedule:

Turin	Bound Brook
Mr. W. Flume	Mr. A. Zimmer
Mr. J. den Pox	Mr. S. Montgomery
Mr. J. Juliano	Mr. H. Cunningham
Mr. C. DeSarlo	Mr. K. Dunn
Mr. C. Burger	Mr. F. Gordon
Mr. M. Colossycx	Mr. L. Bruce
Mr. R. Dilibro	Mr. E. Euchre
	Mr. R. Carter
	Mr. P. Veech
	Mr. O. Otto
	Mr. B. Keen

MARVETTI, INC.

BOUND BROOK, NEW JERSEY

LABORATORY REPORT

To: K. Dunn | Test No. E-470 (PC) T-8 Class "B" Test | Progress Report No. 419

January 28, 1958

First Progress Report of Class "B" Test on Printing Calculator, serial No. P-4 (uncovered), from January 15, 1958 through January 25, 1958.

Total Meter Hours	Total Operations	Total No. Failures	Average Time to Failure
12.9	138,407	12	1.08 hours

Breakdown of Failures:

Unit Affected	No. of Failures	Area Affected
Control Keys	2	(Interlock and equals slide restore cam follower)
Division Mechanism	1	(Division link overload spring)
Keyboard	2	(Interlock)
Multiplier Mechanism	2	(Mult sensor)
Paper Carriage	2	(Platen paper feed)
Rear Selection Carriage	1	(Return control)
Selection Unit	1	(Lower holding pawl)
Symbol Mechanism	1	(Neg equals symbol)
Total Failures	12	

See Service Records No. 1 through No. 12 for detailed information.

Note I: The following Engineering changes were made January 21, 1958:

1. Changed carriage return mechanism to control keyboard interlock properly. (2 keyboard interlock failures listed above)

2. Removed high speed latch, part No. E-470-60-326; part is now obsolete.

3. Changed counter release interponent latch, No. E-470-60-31, for better hold on its operating stud.

Progress
Report No. 419

Note II: Plus or minus bars are interlocked after rapidly going from zero key to plus or minus. H. Shaw states that design of machine allows this; testing to be resumed.

J. P. Black
Product Test Laboratory

JPB/co

cc:
R. Carter

MARVETTI, INC.

BOUND BROOK, NEW JERSEY

LABORATORY REPORT
Test No. E 470 (PC) T-8
Printing Calculator No. P-4 (Uncovered
Class "B" Test
Requested by Product Planning

Progress
Report No. 419-A

April 18, 1958

Summary of failures on Printing Calculator No. P-4 (uncovered), from start of Class "B" test through 50 meter hour Sustained Operational Phase.

Phase of Test	Operating Time	No. of Failures
Shakedown	21.5 meter hours	14
Environmental Operational (low temperature)	1.2 operator hours	6
Note: Test suspended due to repeated failures. See Environmental Operational Phase failure breakdown on page 2.		
Sustained Operational	50.0 meter hours	11
	Total No. of Failures	31

To Vibration Phase:

Total Meter Hours	Total Operations	Total No. of Failures	Average Time to Failure
71.5	772,118	31	2.3 hours

J. P. Black
Product Test Laboratory

I. Shakedown Phase - 21.5 Meter Hours

Unit and Area Affected	No. of Failures
1. Control Keys	2
2. *Keyboard	2
3. Selection Carriage	4
4. Multiplier Mechanism	2
5. Division Mechanism	1
6. Symbol Mechanism	1
7. Paper Carriage	2
Total No. of Failures	14

*Keyboard interlocking after plus or minus has been referred to Engineering.

II. Environmental Operational Phase, $35^{\circ}F$, with prevailing humidity:

Unit and Area Affected	No. of Failures
1. *Lubrication (high viscosity)	5
2. Division Mechanism	1
Total No. of Failures	6

*Four failures at $35^{\circ}F$ and one failure at $45^{\circ}F$ occurred with standard current lubricants in machine. Further Class "A" testing with different lubricants will be conducted at above temperatures.

III. Sustained Operational Phase - 50 Meter Hours

Unit and Area Affected	No. of Failures
1. Symbol Mechanism	1
2. Multiplier Mechanism	2
3. Accumulator	1
4. Motor Mechanism	1
5. Division Mechanism	1
6. Sub Total and Total Cam Follower	1
7. Automatic Back Space Mechanism	1
8. Selection Carriage	2
9. *Undetermined	1
Total No. of Failures	11

*Machine slowed down, then stopped completely after division operation.

Present Status:

The Printing Calculator was taken to R & D on March 11, 1958 and not returned for testing as of this date.

Next phase of test should be the Vibration phase of the Test Criteria.

J. P. Black
Product Test Laboratory

JPB/fa

To: K. Dunn

From: J. P. Black

Progress Report No. 419A Printing Calculator
No. P-4 (uncovered), "B" Test

Further explaining the failure rate on the above test we find that from 55.2 meter hours to 70.5 meter hours represents the longest time between failures, 15.3 meter hours.

This occurred during the 50 meter hour Sustained Operational Phase; there were no failures to conclusion of this phase at 71.5 meter hours. This shows considerable improvement over the 21.5 meter hour Shakedown Phase; the average time to failure in the Shakedown Phase was 1.5 meter hours against the average time of 4.5 meter hours to failure in the Sustained Operational Phase.

J. P. Black
Product Test Laboratory

JPB/co

cc: R. Carter
H. Shaw

MARVETTI, INC.

BOUND BROOK, NEW JERSEY
LABORATORY REPORT
Test No. E-470 (PC) T-8

Printing Calculator No. P-4 (uncovered)
Requested by Product Planning

Report No. 419B*
Sheet No. 1 of 5

July 12, 1958

Previous progress report No. 419A, from start of Class "B" test to vibration phase, issued April 18, 1958.

Total Meter Hours	Total Operations	Total No. of Failures	Average Operation to Failure	Mean Time Between Failures
71.5	772,118	31	24,907	2.3 hours

Progress report from vibration phase through 26.5 meter hours of second 50 meter hour sustained operation phase.

Vibration phase: 8.3 hours
Operator test after vibration phase: 2.0 meter hours, 22,739 operations, no failures.
Sustained operation phase:

Meter Hours	Operations	No.of Failures	Average Operation to Failure	Mean Time Between Failures
26.5	287,728	19	15,144	1.4 hours

Summary of test to date:

Meter Hours	Total Operations	Total No. of Failures	Average Operation to Failure	Mean Time Between Failures
100	1,082,585	50	21,652	2.0 hours

Note: 15.3 meter hours represents the longest time between failures (from 55.2 meter hours to 70.5 meter hours in first sustained operation phase.

Present status of test: Continuing second sustained operation phase pending proper equipment for robot phase of "B" test criteria.

J. P. Black
Product Test Laboratory

JPB/fa

cc: K. Dunn
R. Carter
A. Ammons

*Supplement A of this report (4 pages detailing the failures) has been omitted (Case Writer).

MARVETTI, INC.

BOUND BROOK, NEW JERSEY
LABORATORY REPORT
Test No.E-470 (PC) T-8 Report No. 419C
Class "B" Test
Printing Calculator No. P-4 (uncovered)
Requested by Product Planning

October 30, 1958.

Previous Progress Report No. 419B, from start of Class "B" test through 26.5 meter hours of second 50 meter hour sustained operation phase issued July 12, 1958.

Total Meter Hours	Total Operations	Total No. of Failures	Average Operations to Failure	Mean Time Between Failures
100	1,082,585	50	21,652	2.0 hours

Progress Report from 26.5 meter hours of second 50 meter hour sustained operation phase through 21.9 meter hours of fourth sustained operation phase. (June 10, 1958 to October 24, 1958)

Meter Hours	Operations	Total No. of Failures	Average Operation to Failure	Mean Time Between Failures
95.4	931,006	19	49,000	5.02 hours

Summary of "B" test to date:

Total Meter Hours	Total Operations	Total No. of Failures	Average Operation to Failure	Mean Time Between Failures
195.4	2,013,591	69	29,182	2.83 hours

Note: 27.3 meter hours represents the longest time between failures (from 112.8 to 140.1 meter hours).

Present status of test: Covers installed October 27, 1958 and sustained operation phase continued.

J. P. Black
Product Test Laboratory

JPB/co

cc: K. Dunn
R. Carter
A. Ammons

Report No. 419C
Supplement A

Sustained Operation Phase

Unit and Area Affected	No. of Failures
I. Accumulator:	5

1. No. 1245 spring weak on the fugitive one; installed new No. 1245 spring.

2. Removed interference between credit balance indicator bail and rear pendant arm.

3. a. Installed new transfer pawl in 13th column of accumulator.
   b. Installed new bearing sleeves for the 20 tooth gears.
   c. Installed new No. 1245 springs on transfer pawls on positive side.
   d. Installed new No. 1173 spring on transfer pawls on negative side.

   Note: Inspection revealed 3 loose studs and 1 worn nylon roller on actuator multiplier pawls.

4. Readjusted transfer control bail adjustment for more clearance between bails and transfer pawls.

5. Accumulator opening too wide on negative side; readjusted opening to be equal in the over stroke position. Also replaced weak No. 1064 spring on the accumulator detent arms.

Unit and Area Affected	No. of Failures
II. Backspace Mechanism:	1

1. Overthrow in division during backspace; changed backspace control cam.

III. Clutch Mechanism: 1

1. Gear broke loose from clutch ratchet; installed latest design clutch ratchet and gear, part No. 250240.

IV. Division Mechanism. 1

1. No. 1015 spring too weak on division counter bias bail; replaced with No. 1023 spring.

Report No. 419C
Supplement A

Unit and Area Affected	No. of Failures
V. Memory Mechanism:	2

1. Memory sector restore control out of adjustment; installed larger diameter interchangeable roller on this adjustment.

2. "From Memory" key latch stuck in hole of underlying part; added radius to portion of latch to always overlie hole in underlying part.

VI. Motor: 2

1. Machine slowed down before completing function (occurred twice) due to badly pitted low speed points on motor governor. Points were filed and cleaned, but later it was necessary to install a new motor governor and brushes.

VII. Multiplier Mechanism: 3

1. Loose screw on lifter bail interfered with a cam on rear drive shaft; changed screw and locked it to lifter bail with a jam nut.

   Note: The old design screw in this machine has been replaced with a more reliable design in later models.

2. Over capacity block improperly adjusted; corrected adjustment.

3. Termination control was fractured and bent (part No. E470-60-396); repaired part and provided more clearance between part and its return position to prevent recurrence of fracture. (This had been changed for production model).

VIII. Selection Carriage: 1

1. Check dial restore bar out of adjustment; adjusted restore bar.

IX. Undetermined: 3

1. Incorrect sub total on Accum Equals.
   Printed .00S; should have printed: 2,469,130,864.20S.

2. Errored in division.
   Printed: 4,269.81N ; should have printed: 4,444.44N

   Printed: 1,012.38T (in black); should have printed .00T (in red)

3. Incorrect sub total after minus.
   Printed 111,111,121,212,121.21S; should have printed 111,111,111.10S

Total No. of Failures	19

Engineering changes and R & D inspection results at 178.2 hours:

1. Installed No. 1268 spring, in place of No. 1166 spring,and No. E470-4-27 spring retainer on back space control lever (Part No. E-470-70-108)

2. Installed a nylon bumper, No. E-470-5-324, in place of rubber No. 90028 on the plus-minus pinning stop (left side).

3. Installed No. 1166 spring, in place of No. 1025 spring, on equal key release latch (part No. E-470-60-197).

Inspection Results:

1. Rear carriage return gear sector, part No. E-470-70-67, shows wear on restore tooth.

2. Slight wear on No. 400 roller on the cam follower arm feed gear drive (part No. 255395).

3. Loose rivet on No. E-470-90-74 paper feed drive assembly.

4. Loose taper pin in bellcrank assembly pendant drive (part No. E-470-60-9).

5. The following parts show wear on the cam follower rollers:

   a. Sub Total- Total cam follower assembly (part No. E470-60-45).
   b. Digitation cam follower assembly (part No. E-470-60-47).
   c. Actuator cam follower assembly (part No. E-470-50-94).

   Note: Engineering changes have been made to correct roller wear on future machines.

At 195.4 hours new motor governor and brushes installed, machine washed in Kem Search NC123 (and lubricated) and covers installed.

Operator's Comments:

1. It is possible to depress a digit key too soon after back spacing; setting lever will hang up selection unit and keyboard will be interlocked.

2. If Accum Equals- Transfer Equals is depressed too soon after X2 key the machine will print, but will not go into Accum Equals-Transfer Equals operation.

3. When using Enter Dividend it is necessary to hold key down until selection unit resets to insure correct entry.

4. Back Space key is hard to depress; operators complain of shoulder pains after extensive use.

J. P. Black
Product Test Laboratory

JPB/co

cc: K. Dunn
R. Carter
A. Ammons

MARVETTI, INC.

BOUND BROOK, NEW JERSEY

LABORATORY REPORT — Report No. 419-D
Test No. E-470 (PC) T-8
Class "B" Test
Printing Calculator No. P-4 (covered)
Requested by Product Planning

Previous Progress Report No. 419-C, Dated October 30, 1958. Summary of "B" Test to that date.

Total Meter Hours	Total Cycles	Total No. of Failures	Average Cycles To Failure	Mean Time Between Failures
195.4	2,013,591	69	29,182	2.83 Meter Hours
Operator Hours				**Mean Time Between Failures**
591.8	2,013,591	69	29,182	8.57 Operator Hours

Due to no robot test equipment designed, machine was placed on sustained operational phases to substitute.

Status of test to date January 30, 1959 as follows:

Total Meter Hours	Total Cycles	Total No. of Failures	Average Cycles to Failure	Mean Time Between Failures
254.1	2,588,586	80	32,357	3.17 Meter Hours
Operator Hours				**Mean Time Between Failures**
759.2	2,588,586	80	32,357	9.49 Operator Hours

Test was suspended at this point by R & D and Product Planning, due to no automatic equipment for robot test phase.

J. P. Black
Product Test Laboratory

cc: K. Dunn
S. Klamask

MARVETTI, INC. (D)

Design and Development of a Printing Calculator

As tools for the printing calculator were completed in Europe they were shipped to Bound Brook, where pilot production was to begin. The first machine assembled during Bound Brook pilot production with tool-made parts was completed in October 1959. This date can thus be taken as marking the start of production debugging of the printing calculator. Pilot production continued at Bound Brook until February 1960. A total of about 50 machines were built. During this time a group of five people who were to form the nucleus of the repair, assembly and service personnel at the Hanover plant was brought from Europe to Bound Brook to learn as much as possible about the machines. The first of these people arrived in the summer of 1959. By August enough tool-made parts were available to begin making subassemblies. When Bound Brook pilot production began in October the assembly operations were carried out by only a few people, mainly by the five from Hanover; the machines were not actually built on an assembly line.

By January 1960 "C" tests had begun on the first pilot production machines. These would have to be satisfactorily completed before the printing calculator could be released for general sale.

During June 1960 the complete pilot production line was transferred to the Hanover plant. Pilot production commenced at Hanover in March. Meanwhile "C" testing and debugging continued at Bound Brook.

Production Debugging

By the end of Bound Brook pilot production, ten printing calculators were on "C" test in the Bound Brook Product Test Laboratory. As pilot production got under way at Hanover, machines were put on "C" test there. In October 1960 five machines were on "C" test at Hanover and two were on "C" test at Bound Brook. Production at Hanover was then at the rate of three machines per day and one machine per week was being placed on "C" test. The tentative goal for full production, achievement of which was expected around December 1961, was 60 to 80 machines per day. This figure was based on sales estimates.

In April 1960 Art Coles replaced Harvey Shaw as Project Engineer on the printing calculator. Mr. Coles was to complete the production debugging, leaving Mr. Shaw free to devote his time to newer projects. Mr. Coles had been with Marvetti for 25 years, beginning in the factory as an assembler. He had worked in the Calculator Section of R & D on both adding machines and rotary calculators before taking over the printing calculator project. There had been only two to three men on the project since 1959. His first connection with the printing calculator had come in the spring of 1959 when he spent a month hand-building the parts for, and assembling, two prototype machines, along with a man each from the assembly and service departments. This was to allow all three to familiarize themselves with the design, construction and operation of the calculator. Then from May 1959 to April 1960 Mr. Coles worked on the development of a new rotary calculator.

In June of 1960, Mr. Coles went to Hanover to watch over early production at close range. He explained that during this period the assembly and subassembly lines were bring built up with all new untrained personnel making parts and performing assembly operations. Almost all parts were being made in Hanover; exceptions were injection moded plastic parts and those which had to be copper brazed. These operations were being performed at Bound Brook, but facilities for both were expected to be available at Hanover sometime in 1961. All of the Hanover personnel had to be trained by those few who had been at Bound Brook during earlier pilot production. The inexperience of the personnel coupled with the fact that much of the European-built tooling had been made by people unfamilar with U.S. engineering practices led to many problems and to poor performance of early machines. Mr. Coles noted that the purpose of the Bound Brook pilot operations had been mainly to remove any last remaining engineering problems from the calculator. The problems encountered in Hanover could, in general, be termed manufacturing problems rather than engineering design problems.

Besides simple mistakes in the assembly of the machines, Mr. Coles mentioned that much trouble was caused by such things as poor riveting and defective heat treating. At first, he said, some parts were not being heat treated to the correct hardness and thus wore out quickly, while others were being case hardened to too great a depth, so that they were brittle and broke while being formed for adjustment.

In his capacity as Project Engineer, Mr. Coles was concerned with both manufacturing problems and engineering problems. Problems showed up both on production testing -- which is done on all machines to insure that they function correctly -- and on the much more exhaustive "C" tests which some machines underwent. Mr. Coles said that when a machine failed while on "C" test, or gave wrong answers, he would be notified by the test lab. Then he would try to analyze the problem and determine if it had been caused by faulty assembly, by defective parts or by poor design. He said that it is usually necessary to actually dismantle and work with the malfunctioning machine to find the trouble.

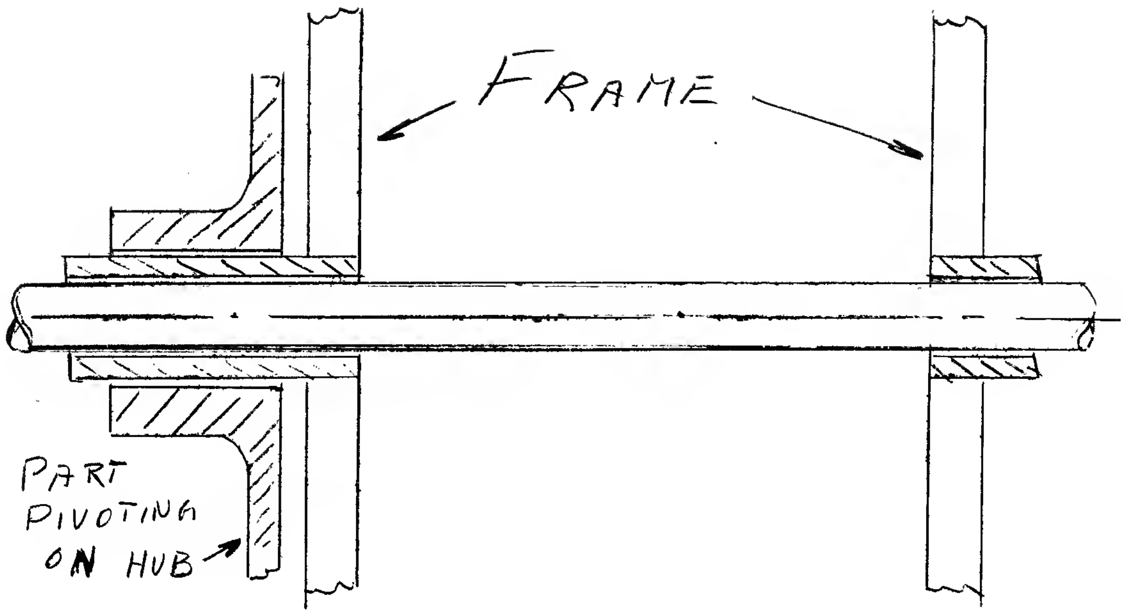
Beginning in the spring of 1960, a number of printing calculators were placed in Marvetti's offices to be tested under normal consumer conditions. Mr. Coles also watched these machines for problems.

When he feels that he has isolated a problem, Mr. Coles is free to specify design changes, or changes in assembly operations, fixtures, other tooling, inspection or adjustment procedures, or any of the other steps in the manufacturing process as he sees fit. In instances where design changes will affect the functional characteristics of the machine he must secure approval from the Product Planning Department. The forms upon which engineering changes are recorded appear in Exhibits 1 and 2.

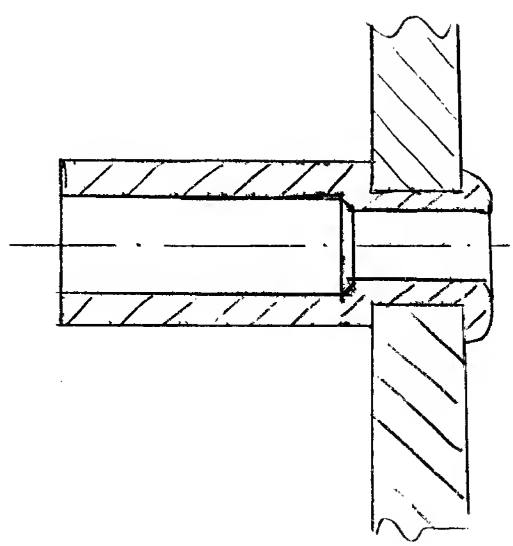
Mr. Coles pointed out that all changes are still subject to confirmation by test. In the production debugging stage of development, it is usually necessary to build and test four or five machines which incorporate the change. Mr. Coles said that some of the changes at this stage are quite obvious, involving several of the parts among the 5000 total which may have been overlooked earlier. This is particularly true when it comes to decreasing the cost of parts, which is often easy to do and may result in considerable savings. Mr. Coles also pointed out that sometimes the design of a part is changed slightly after release to manufacturing so that the tooling is easier to make; such small changes may have unexpected and adverse effects on performance.

Typical of the problems Mr. Coles encountered were several concerning the design of springs in the printing calculator. Of these, many are identical; some because they perform the same functions in the different orders, others because it is expedient -- obviously, the fewer different springs the factory must make and stock, the better. Mr. Coles said that often springs which work satisfactorily in hand-built prototypes are too light for consistent performance in production machines. Because there is more variability in the fits of the moving parts and sometimes unexpected friction loads in the production machines, the springs may have to exert a greater force than in freer hand-built models. The objective is the lightest spring that will work well, so that forces and deflections are minimized, but often the springs originally specified proved too light. The force exerted by these was increased by increasing the wire diameter or the initial tension.

Another general class of problems Mr. Coles encountered concerned the bearings on which the many shafts in the machine rotate or oscillate. Such bearings are normally sleeves fixed to frames. Often these bearings are quite long in relation to shaft diameter because other parts must pivot on the outer diameter of the bearing sleeve, or hub, as shown in the sketch which follows:



After a machine has been in service for some time, the frames may shift. Long bearings such as those shown above then tend to bind the shaft; the misalignment may prevent rotation or may merely result in excessive wear. Such a problem occurred with the bearings carrying the shaft upon which the multiplier sensor gear, shown in Exhibit 3, rides. Only one of the bearings appears in the drawing. As a remedy, Mr. Coles ordered counterbores in the bearings as illustrated below:



This eliminated possible binding problems if the two frames were not well aligned when assembled or shifted out of alignment later

Mr. Coles also said that in one instance in the original design a shaft had been carried in three bearings. The designers had used an extra bearing to insure against shaft deflection. The center bearing was designed to be adjustable for proper alignment. However, shaft straightness was not always maintained, and shaft binding occurred in many machines. After checking into the problem, it was found that a slight amount of shaft deflection could be tolerated. An example of a three bearing shaft was the clutch throwout shaft which is visible in Exhibit 4. The bore of the middle bearing was increased sufficiently so that misalignment and binding would no longer be a problem. In none of the instances where this was done did shaft deflection subsequently prove to be a problem.

Mr. Coles also encountered several instances where two or more shafts carrying mating parts were located axially from different frames. This led to part position and alignment problems when the frames shifted, and the design was changed where possible so that shafts would be located from a single frame.

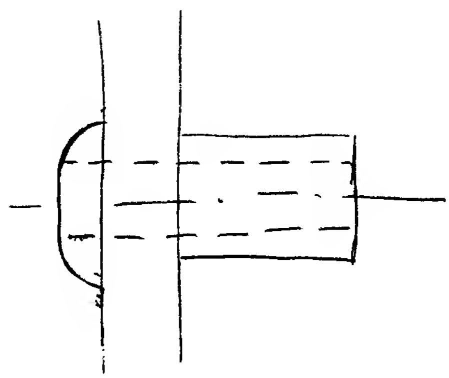
Further problems which Mr. Coles encountered during production debugging are presented below:

Problem 1 -- Accumulator

The operation of the accumulator has been previously described in part B of the case. The assembly was shown in Exhibit 5 of part B. When attempting to determine the cause of answers incorrect by one digit (in one of the registers) on test machines, Mr. Coles found that, because the sizes of the bearing bores of the gears involved varied, there would sometimes be enough drag in the assembly so that one of the pendant or feed gears would miss a tooth. This resulted in an entry into the accum ulator gear off by one. The rear pendant gears and the feed gears rotate on fixed shafts. The position of the feed gear carrier determines whether entries to the accumulator will be positive or negative. The feed gear carrier is located by a stop, not shown in the drawing of Exhibit 5 of Part B, which is fixed to the frame. The location of the pendant may be changed; this allows the mesh of the feed gears with the pendant gears to be adjusted. A drawing of the feed gear appears in Exhibit 5, one of the feed gear and hub assembly in Exhibit 6. These parts were the same as used in the accumulator of Marvetti's adding machine. The feed gear carrier is shown in Exhibit 7. The feed gear block, shown in Exhibit 4 of part B, is intended to keep the feed gear (and thus also the accumulator gear) from turning when it is not in mesh with either of the pendant gears. The two pieces of the block are shown in Exhibits 8 and 9. The assembly appears in Exhibit 10. The block was added during the early prototype stage in an attempt to cure errors.

Problem 2 -- Multiplier Sector Detent

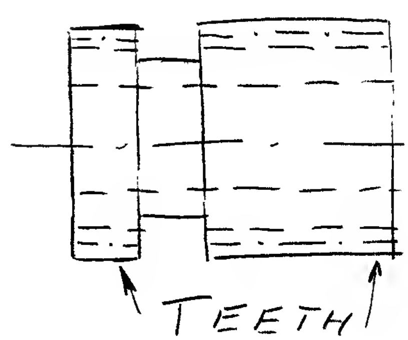
The multiplier sector detent which appears in Exhibit 11 acts as both a detent to lock the storage unit sector in a given position and as an aligner to locate another part which is not shown. The detent pivots on a riveted hub as shown below:



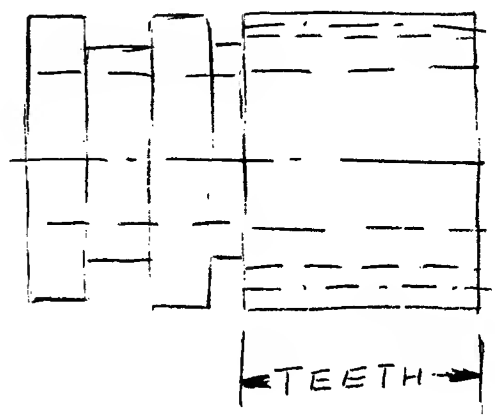
This riveted hub would loosen after the calculator had been operated for a time; the detent could then slip free, resulting in an error. Mr. Coles determined that the trouble was not being caused by faulty riveting; the greater than normal load on the hub imposed by the detent's added function as a division aligner was too great for the rivet to carry indefinitely.

Problem 3 -- Multiplier Sensor Gear

The multiplier sensing unit, shown in Exhibit 12, moves linearly in and out to sense the number appearing on the short cut multiplier sector. The assembly also appears in Exhibit 7 of part B. When the square shaft on which the multiplier sensor gear rides is unlatched the sensing unit is allowed to drop down to the sector, turning the gear and shaft. The original design of the multiplier sensor gear is sketched below:



The gear had teeth on its entire circumference; the groove was cut for a forked guide, then the teeth were milled the full width of the gear, on both sides of the groove. The sharp corners of the gear teeth would catch on the forked guide. The gear cost 12 cents to make. In July 1960 the gear was redisigned as shown below:



A second grooved relief was added and teeth hobbed up to this relief. This part cost 28 cents to make. Both gears had a square broached hole for the shaft. Mr. Coles was unhappy with the high cost of the new part.

Problem 4 -- Multiplier Ratchet

The multiplier ratchet also appears in Exhibit 12. There is one tooth spaced differently from the rest just to the right of the arrowhead in the leftmost drawing. This tooth is under the counter ratchet detent when at the zero position and the odd tooth provides desirable clearance in another part of the mechanism. This is the form the ratchet took on the first prototype machines; the ratchets were made on a milling machine. On later prototypes the ratchets were cut with all teeth identically spaced, this being considerably easier. In production the ratchet was to be a stamped part; however, apparently through some oversight, the dies were made with all teeth identical. Perhaps the drawings were never changed back to the original form with the one odd tooth. The calculator will operate with a ratchet having all teeth identical; however, much more frequent adjustments are required and reliability suffers. The ratchet is .125 inch thick. Two blank and three shave dies are used in its production; they are expensive. The ratchet is attached to its shaft by a hub; there is a drilled and tapped set screw hole in the hub.

RESEARCH AND DEVELOPMENT DEPARTMENT

CHANGE AUTHORIZATION

NO. ____________

DATE ____________

PROJECT TITLE & E No. F 73 - ____________

DESCRIPTION OF CHANGE:

REASON FOR CHANGE:

PRIORITY NO. ________ WHEN EFFECTIVE ____________ MODEL AFFECTED ____________

REMARKS:

APPROVED ____________

____

RECOMMENDED BY ____________

PREPARED BY ____________

PROJECT ENGR. ____________

APPROVED ____________
MANAGER RESEARCH AND DEVELOPMENT

RECEIVED ____________

BY ____________
FACTORY MANAGER

Form No. 400 - 1 5/1

ECL 45-D
Exhibit 2

RESEARCH & DEVELOPMENT DEPT.
PARTS LIST

"E" No.__________ Date__________ For Model__________________________

(1)	(2)	(3)			(4)	(5)		(6)		(7)	(8)		(9)
"E" NUMBER OR PRODUCTION NUMBER	REPLACES PRODUCTION NO. "E" NO. OR "NEW"	CHECK ONE			QUANTITY REQ'D. Released Part Per Machine	USED ON AND/OR WITH PART NUMBER(S)		INTERCHANGEABLE FOR SERVICE (Check One)		PRODUCTION NUMBER (FOR Use of Prod. Eng.)	USAGE CHANGE		REMARKS
		EXHAUST	REOPERATE	SCRAP		Used With	Used On	Yes	No		QUAN. INCREASED (Existing Part)	QUAN. DECREASED (Existing Part)	

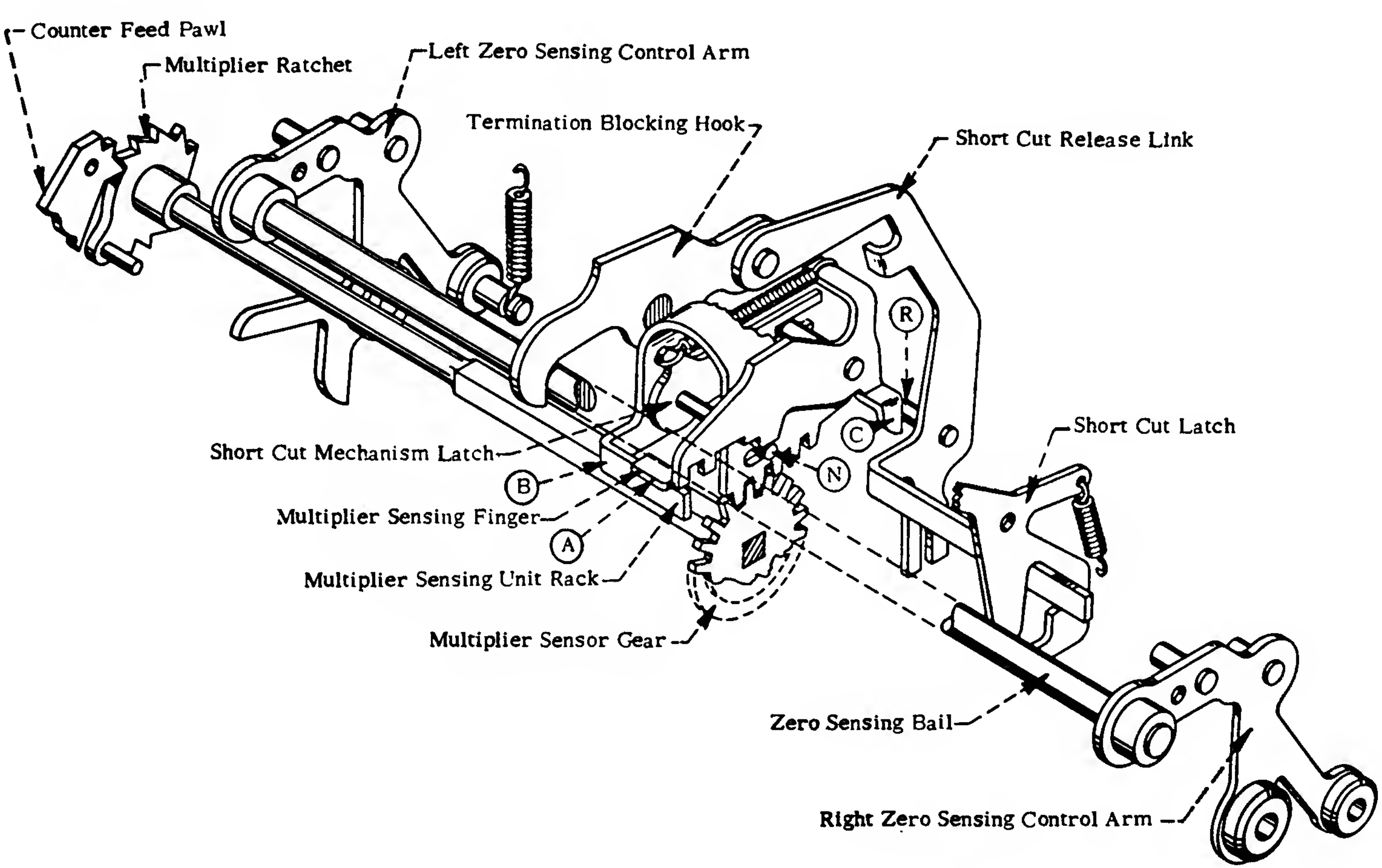


Exhibit 3: A Portion of the Multiplication Mechanism.

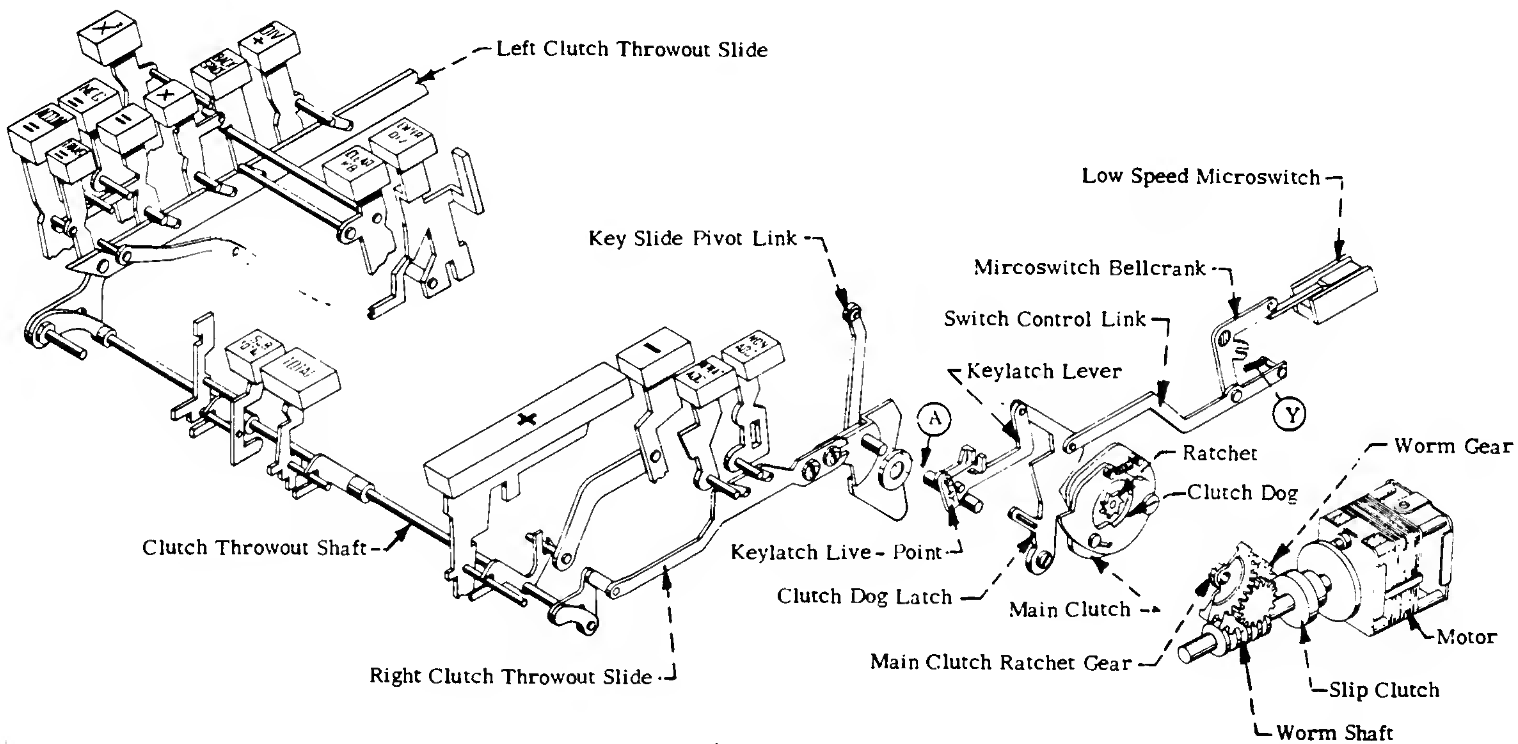
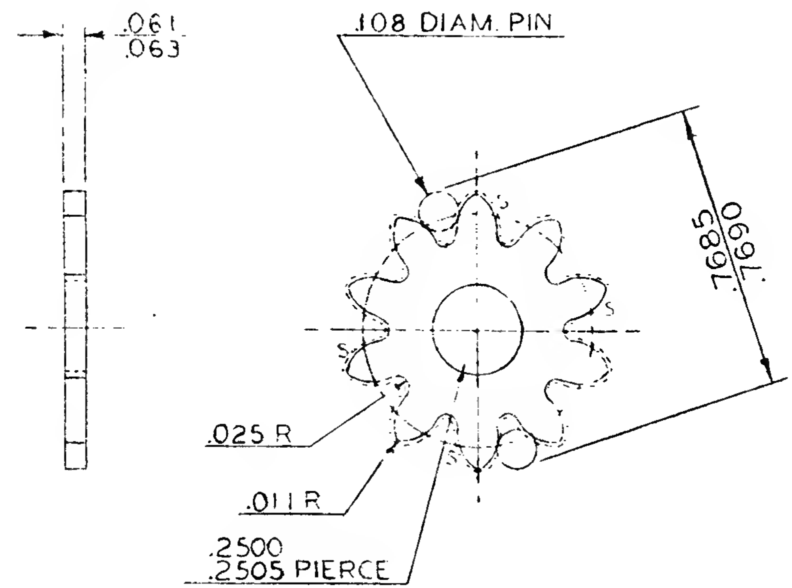


Exhibit 4: A Portion of the Motor and Drive Assembly Including the Clutch Throwout Shaft.

DEPT. 75 RESEARCH

240051

STAN	USED ON
1	2401



GEAR DATA
30° PRESSURE ANGLE
16 DIAMETRAL PITCH
10 TEETH-INVOLUTE
.6183 /.6188 PITCH DIAM
.1348 TOOTH DEPTH
.742/.744 O. D.

Exhibit 5: Feed Gear.

X 3

HEAT TREAT	REVISIONS						NAME ACCUMULATOR FEED GEAR	
CARBURIZE		1 12-11-47	2 9-16-48	3 1-8-49	4 3-11-49	5 4-14-49		
1550° — 1600° F.	6	7	8	9	10	11	MATERIAL .063 X 1" B.R.S. (57-7 R.B.)	MS 2-
.006 —.008 CASE	12	13	14	15	16	17	DRAWN BY J.H.M. DATE 9-6-47; EXP. NO. E-179-B	SCALE 2 TO 1
OIL QUENCH	18	19	20	21	22	23	REDRAWN FROM J.H.M. 9-2-47; -5A	PART NO. 240051
FINISH JETAL							CHECKED AUTH 9-12-47	

240150

QUAN	USED ON
11	
11	
11	
11	
11	
11	
11	
11	
11	
11	

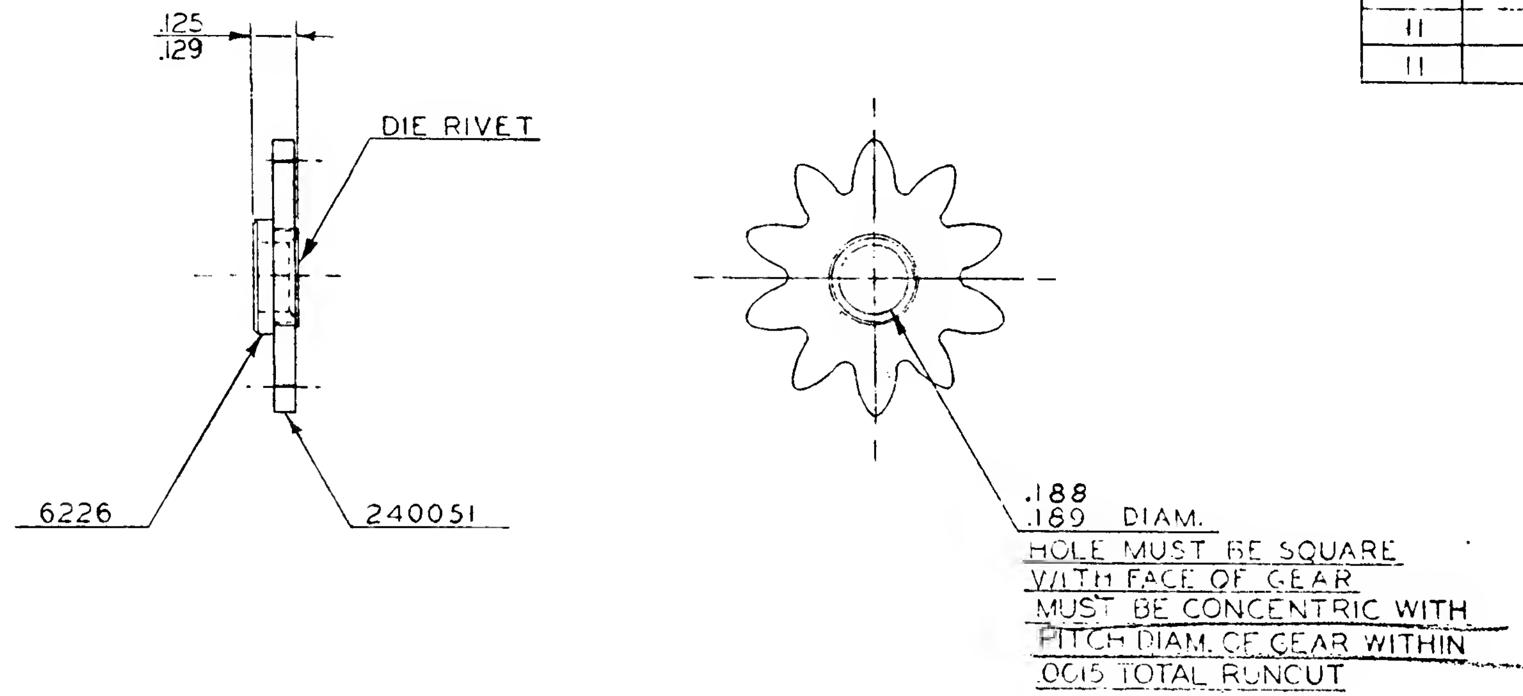


Exhibit 6: Feed Gear and Hub Assembly.

X-8

HEAT TREAT NONE	1	2	3	4	5	NAME ACCUMULATOR FEED GEAR ASSEMBLY	
	6	7	8	9	10	11	MATERIAL
	12	13	14	15	16	17	DRAWN BY J.F.R. DATE 3-17-50	EXP. NO. E-179-B -125B	SCALE 2 TO 1
	18	19	20	21	22	23	REDRAWN FROM	PART NO. 240150
FINISH NONE	REDRAWN FROM P.L. 12-6-49						CHECKED AUTH 3-17-50

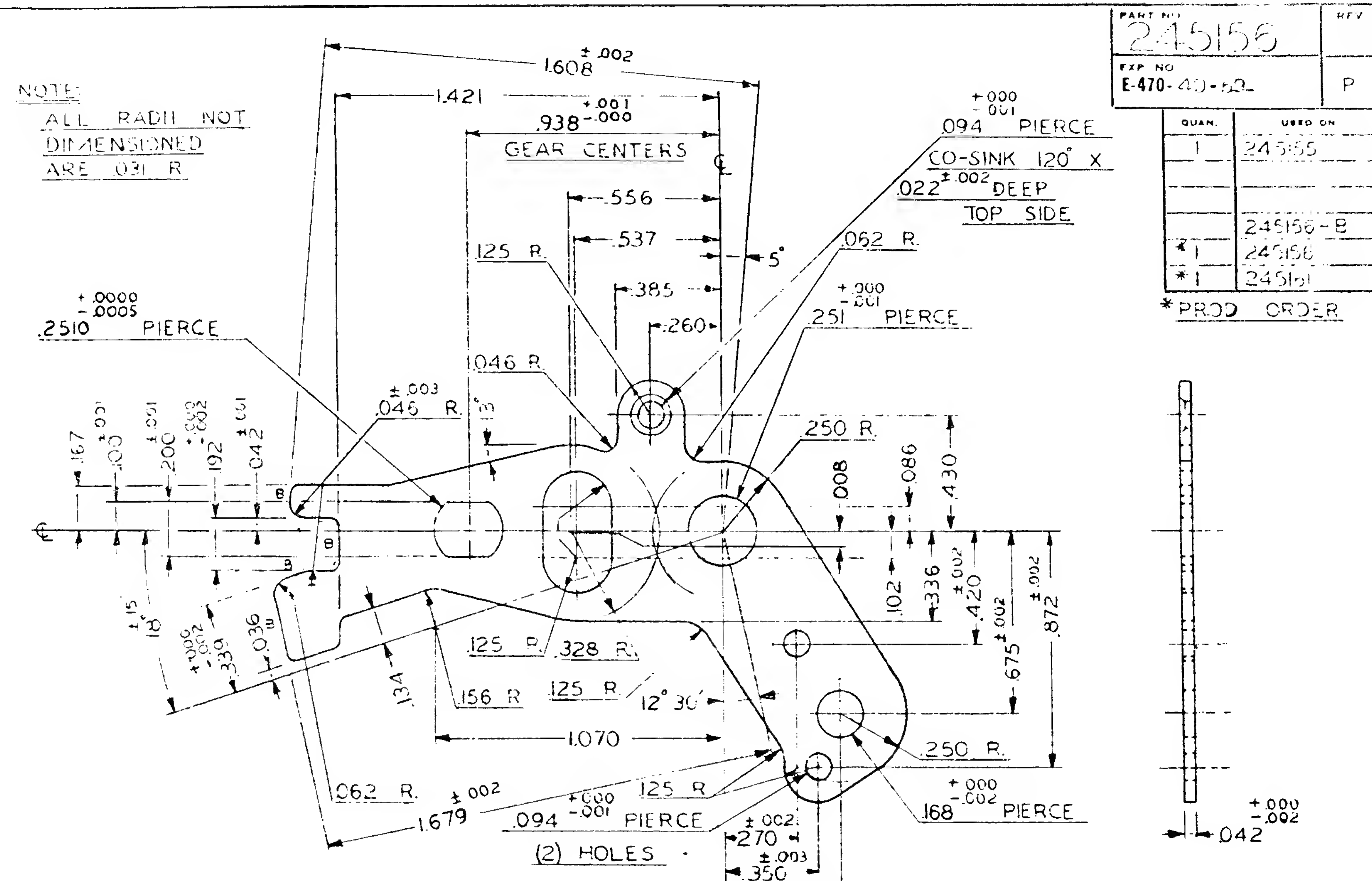


Exhibit 7: Feed Gear Carrier.

HEAT TREAT NONE	TOLERANCES	REVISIONS 1	2	3	NAME CARRIER - FEED GEAR - LEFT		
	UNLESS OTHERWISE SPECIFIED	4	5 6	7	MATERIAL .042 X BRSTEEL (57-72FB) MS2 -		
	DIMENSIONAL = ±.005	8	9 10	11	DRAWN BY E. L. DATE 1-7-58	RESEARCH AUTH NO	SCALE 2 TO 1
		12	13 14	15	REDRAWN FROM	805-F	PART NO 245156
FINISH NONE	ANGULAR = ±30°	16	17 18	19	CHECKED AUTH.		

DEPT. 400 - MASTER
PART NO. 255667

EXP NO	
E-470-40-168	A

QUAN	USED ON
2	255665

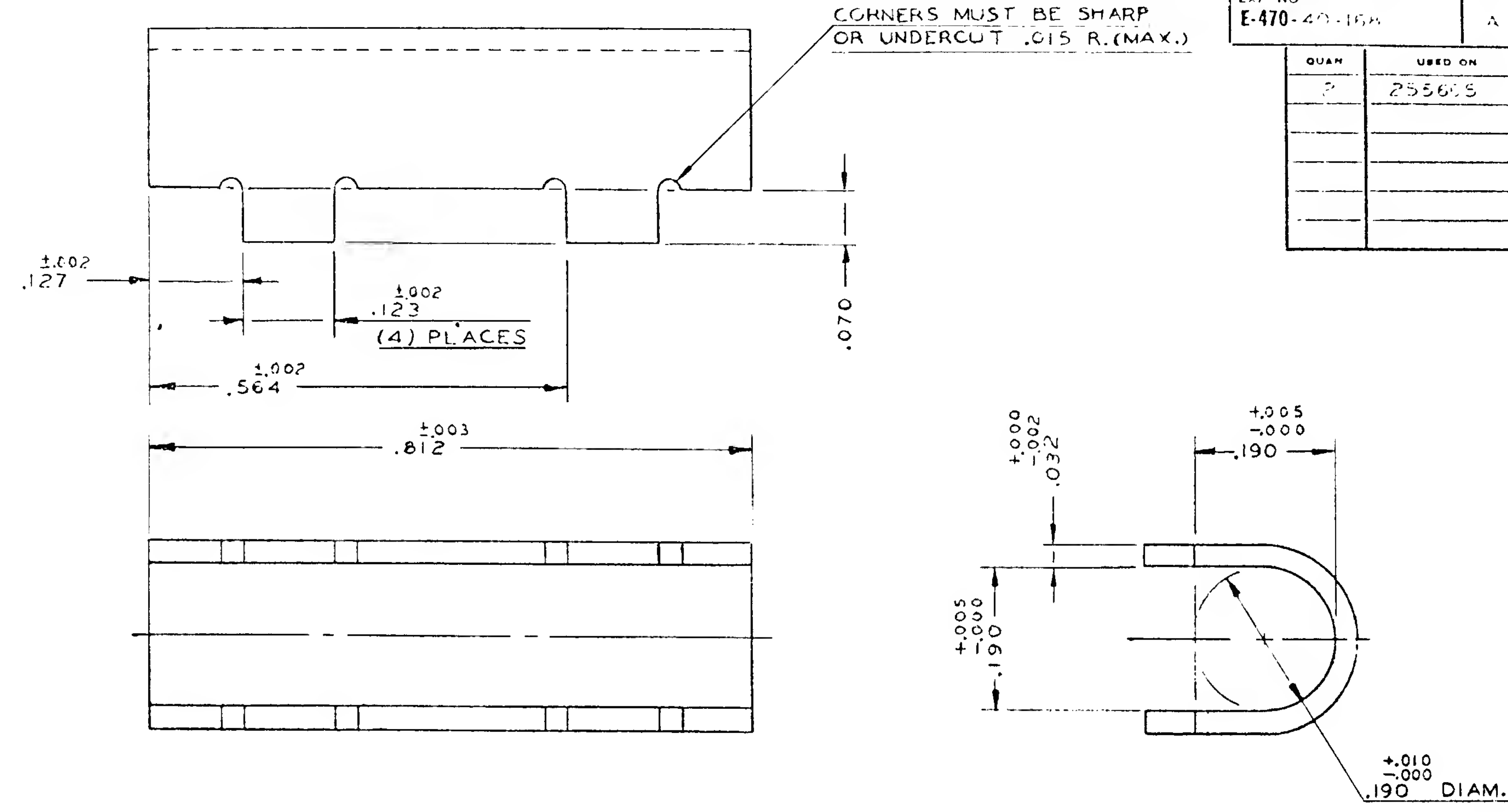


Exhibit 8: One Piece of the Feed Gear Block.

HEAT TREAT	NONE	TOLERANCES	REVISIONS 1	2	3
		UNLESS OTHERWISE SPECIFIED	4	5	6	7
		DIMENSIONAL = ±.005	8	9	10	11
			12	13	14	15
FINISH	NONE	ANGULAR = ±	16	17	18	19

NAME BLOCK - BEARING STRAP - OVERTHROW
MATERIAL .032 X B.P. STEEL (57-72 RB) MS2-
DRAWN BY T. W. DATE 1-7-58 RESEARCH AUTH. NO. 805-F SCALE 5 TO 1
REDRAWN FROM
CHECKED AUTH.
PART NO. 255667

FORM 43-71

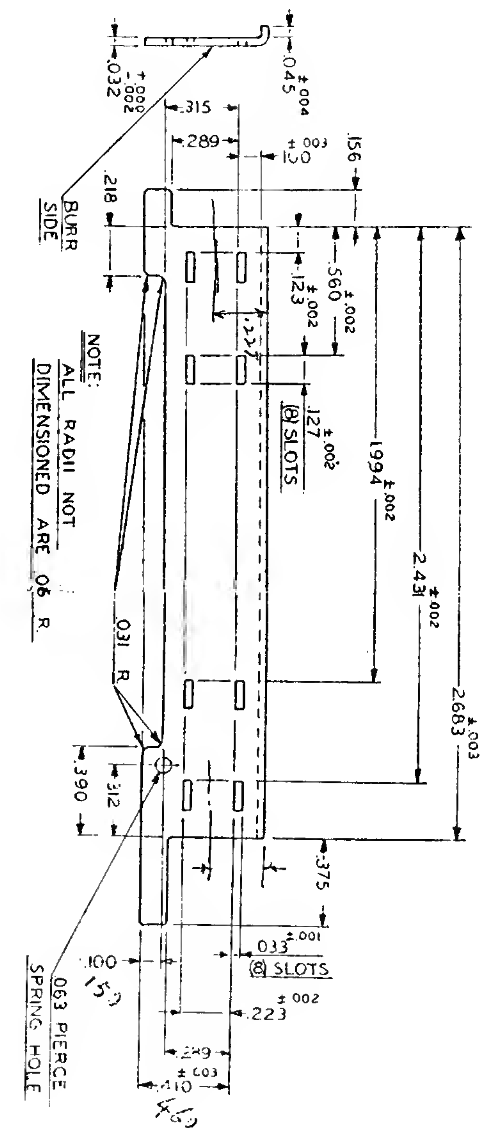


Exhibit 9: Second Piece of Feed Gear Block.

HEAT TREAT NONE
FINISH NONE

TOLERANCES
UNLESS OTHERWISE SPECIFIED
DIMENSIONAL — ±.005
ANGULAR — ±30'

REVISIONS 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19

NAME BLOCK — FEED GEAR OVERTHROW
MATERIAL .032X BP STEEL (57-72RE) MS2 - C
DRAWN BY E. L. DATE 1-7-58
REDRAWN FROM
CHECKED AUTH
RESEARCH AUTH NO 805-F
SCALE 2 TO 1
PART NO 255666

PART NO.	
255665	
EXP. NO. E470-60-170	L

QUAN.	USED ON
1	PC1217

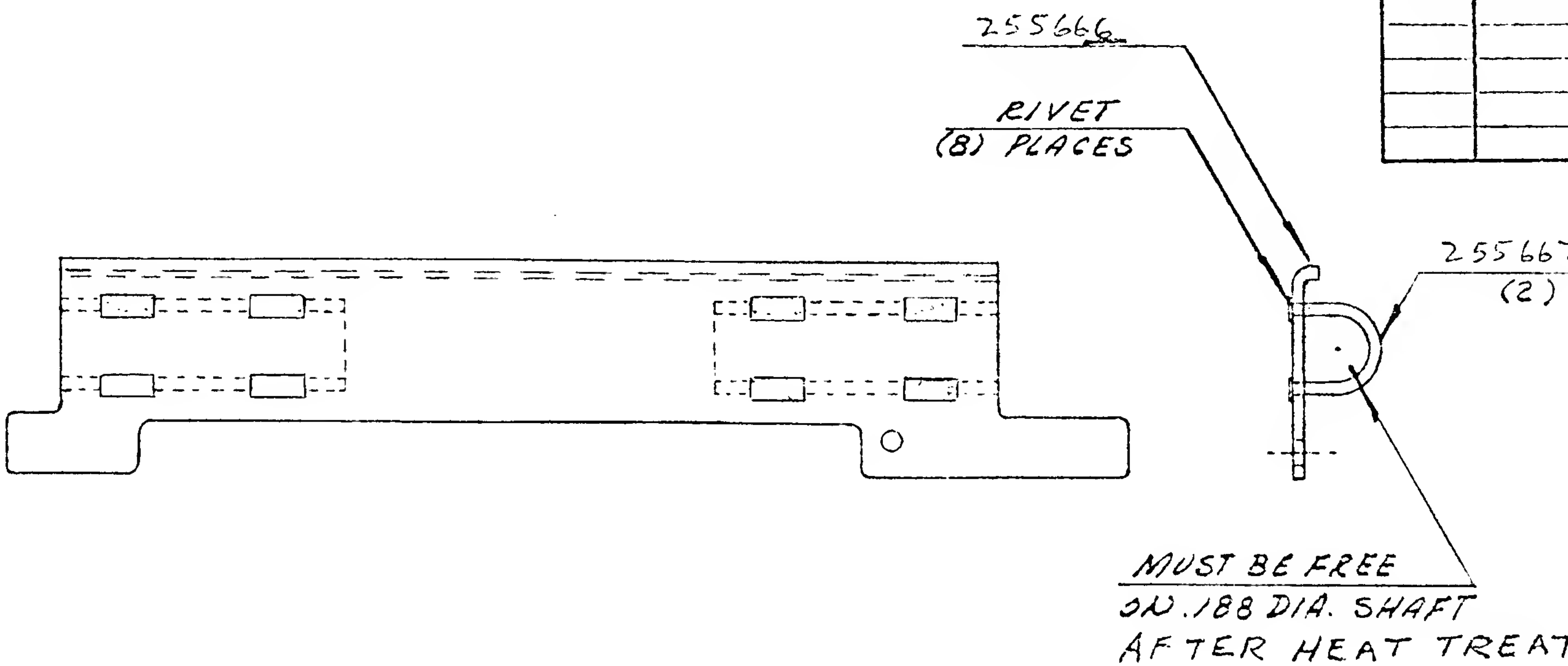
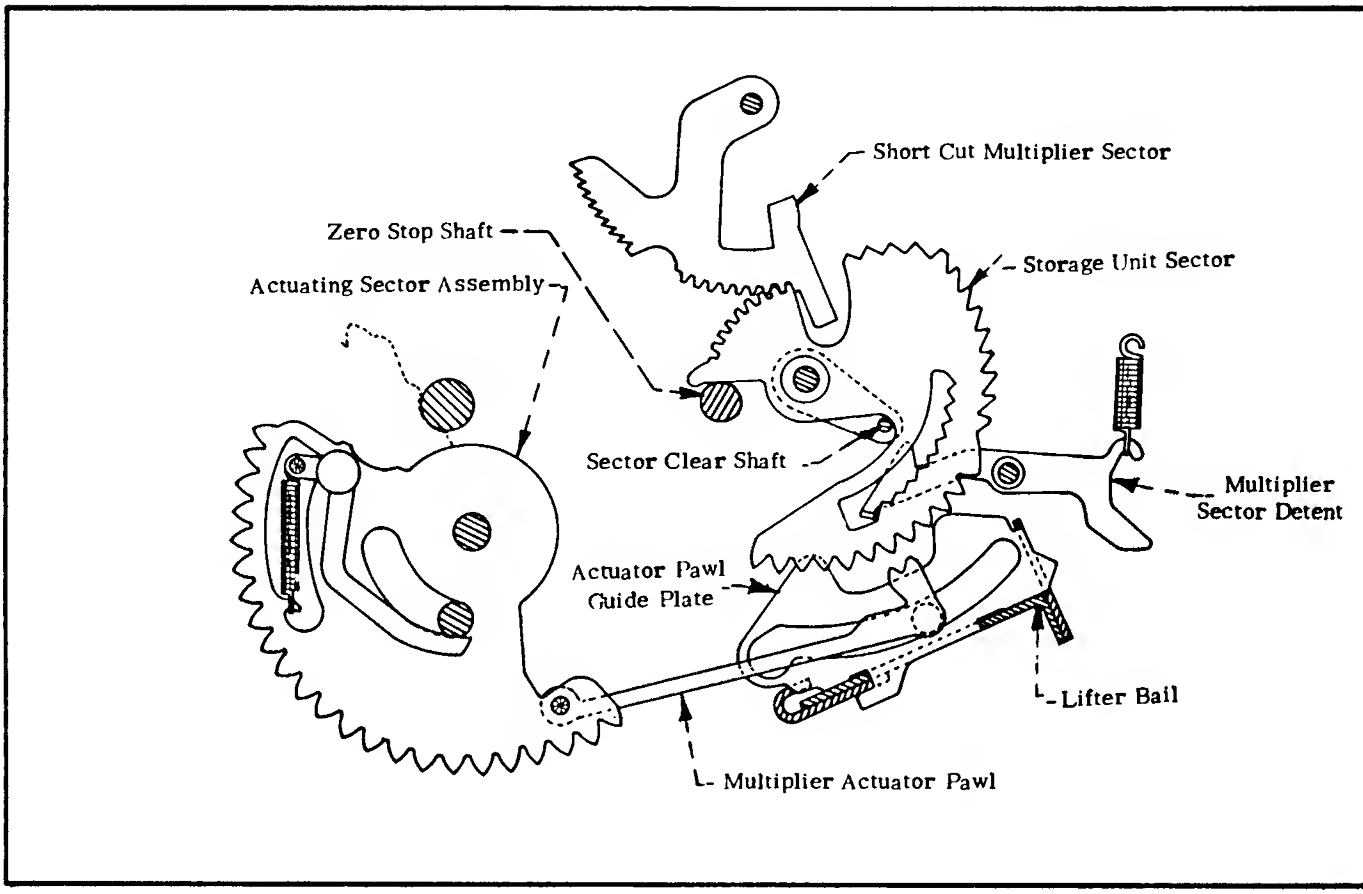


Exhibit 10: Feed Gear Block Assembly.

X-1

HEAT TREAT CARBURIZE	TOLERANCES		1	2	3	NAME BLOCK ASSEMBLY – FEED GEAR OVERTHROW	
1550° - 1600° F.	UNLESS OTHERWISE SPECIFIED	4	5	6	7	MATERIAL	
.004 - .006 CASE	DIMENSIONAL = ±	8	9	10	11	DRAWN BY — DATE 1-7-58	RESEARCH AUTH. NO. 805-F / SCALE 2701
OIL QUENCH		12	13	14	15	REDRAWN FROM	PART NO. 255665
FINISH NICKEL OR CADMIUM	ANGULAR = ±	16	17	18	19	CHECKED — AUTH 1-7-58	

FORM 43-1



<u>Exhibit 11:</u> A Portion of the Memory Unit Mechanism Including the Multiplier Sector Detent.

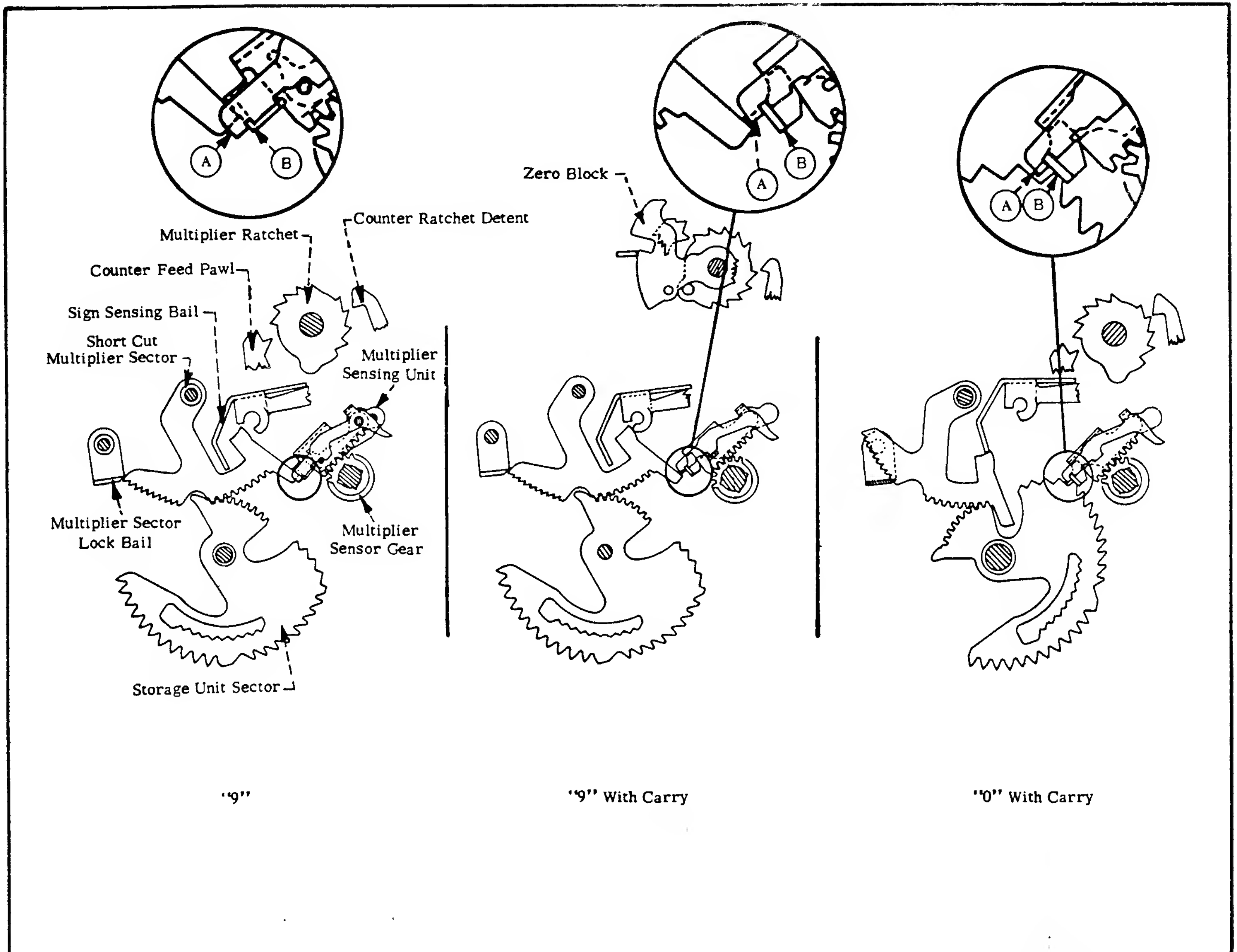


Exhibit 12: **A Portion of the Multiplication Mechanism Including the Multiplier** Sensing Unit **and Multiplier Ratchet.**

MARVETTI, INC. (E)

Design and Development of a Printing Calculator

During production debugging in 1960, Art Coles, Project Engineer on the printing calculator, uncovered a number of problems which led to poor performance of the machines in terms of both accuracy and reliability. His solutions to several were as follows:

Problem 1 -- Accumulator

Mr. Coles attacked the problem of skipped teeth in the rear pendant-to-accumulator gear train by modifying the slot in the end of the feed gear carrier. The slot had provided clearance around the pendant gear shafts; now it was used to locate the feed gear shaft. See Exhibit 5 of part B. The springs force the feed gear carrier against the shaft and a constant center distance between pendant and feed gears is maintained. The redesigned feed gear carrier is shown in Exhibit 1.

Next the feed gear carrier stop was removed from the frame of the machine. It was omitted entirely. This became possible when the feed gear was redesigned as a sintered steel part with an integral hub (see Exhibit 2). Tolerance build-ups are less with the one-piece gear and hub. Since the sintered gear was not in the earlier prototypes, this block had been needed to ensure that tolerance variances in the pitch diameter of the feed gears did not permit them to rotate too far.

Problem 2 -- Multiplier Sector Detent

In order to fasten the hub to the multiplier sector detent more securely, Mr. Coles specified in May 1960 that the hub be copper brazed to the detent after riveting. He said that furnace brazing was used in such instances, the parts to be brazed traveling through a 2000°F. furnace on a moving conveyor. Three possible mean of getting the copper

to the joint area were available to him; use of a copper plated hub, a copper ring placed around the hub, or copper paste. Mr. Coles chose to copper plate the hub. He explained that tolerances had to be tightened on the mating parts since the fit is very important for a successful brazed joint. The copper is actually drawn into the gap between the parts when they pass through the furnace. He mentioned that many parts in the printing calculator are now being copper brazed for increased strength, but that, since the Hanover plant does not yet have facilities for brazing, the parts must be made in West Germany, shipped to Bound Brook for brazing, and then shipped back to Hanover.

Problem 3 -- Multiplier Sensor Gear

To replace the multiplier sensor gear with two relief grooves and hobbed teeth, which cost 28 cents, Mr. Coles specified a sintered steel gear in October 1960. The sintered gear requires no machining operations and costs 6 cents to make.

Problem 4 -- Multiplier Ratchet

Mr. Coles specified that the new ratchet be made of sintered steel. This resulted in a significant cost saving. The only machining necessary on the sintered metal part is the drilling and tapping of the setscrew hole in the hub.

The printing calculator was placed on sale in 1961, after 350 machines had been built -- enough to fill the distribution channels and provide at least one machine for each sales office.

ECL 45-E
Exhibit 1

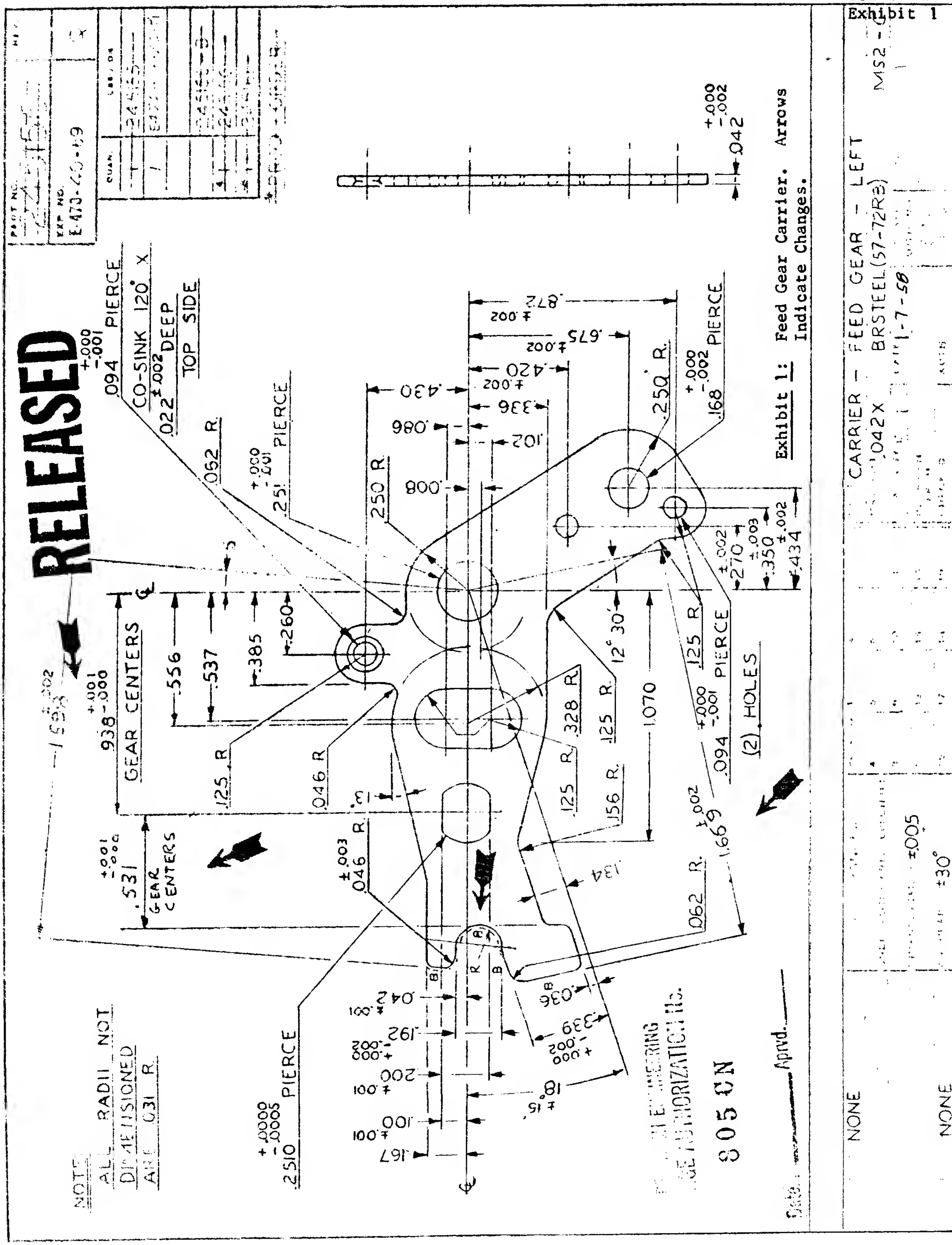


Exhibit 1: Feed Gear Carrier. Arrows Indicate Changes.

DEPT. 400 - RESEARCH

PART NO. 255158		REV. 1
EXP. NO. E-410-40-83		6
QUAN	USED ON	
17	1217	
13	1213	

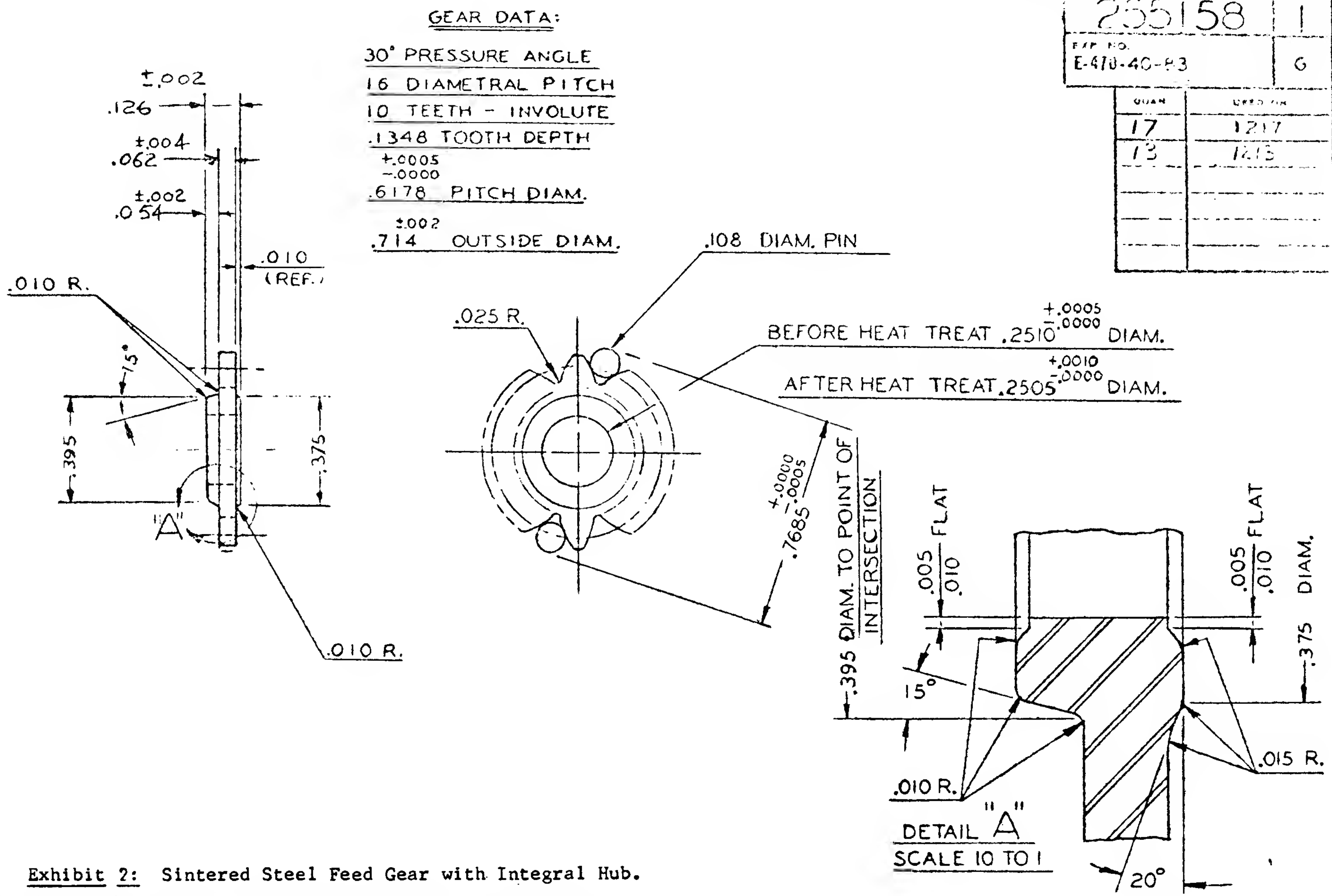


Exhibit 2: Sintered Steel Feed Gear with Integral Hub.

HEAT TREAT CARBURIZE 1550° - 1600° F. .005 - .007 CASE OIL QUENCH	TOLERANCES UNLESS OTHERWISE SPECIFIED DIMENSIONAL ±.005 ANGULAR — ± 30′	REVISIONS 1 6-3-60	NAME GEAR - ACCUMULATOR FEED
FINISH NONE			MATERIAL PURCHASE - #10101 CEROMET SINTERED STEEL
			DRAWN BY T. W.	DATE 1-7-58	RESEARCH AUTH. NO. 805-CM	SCALE 2 TO 1
			REDRAWN FROM	CHECKED	AUTH. 1-27-60	PART NO. 255158